SOME ANALYSES OF PLEISTOCENE DEPOSITS IN THE EDMONTON AREA

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The undersigned hereby certify that they have read and recommend to the School of Graduate Studies for acceptance, a thesis entitled "Some Analyses of Pleistocene Deposits in the Edmonton Area" submitted by Denny Emerson Duff, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

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April 1951.

Apr. 18/51

THE UNIVERSITY OF ALBERTA

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in the

EDMONTON AREA

A DISSERTATION

SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

FACULTY OF ARTS AND SCIENCE

by

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EDMONTON, ALBERTA

APRIL 1951.

A B S T R A C T

This thesis embodies the results of a detailed investigation of the sands and sand fractions of till sheets of Pleistocene age in the Edmonton map-area.to ascertain if a correlation of these sands and till sheets is possible.

Observed field data, mechanical analyses, histograms, graphs, heavy minerals and sphericity-roundness data are the methods of approach utilized in attempting this correlation and the various techniques employed in this investigation are described.

The investigation reveals the presence of three distinct till sheets and two sets of interglacial beds. Histograms and sphericity data present a possible means of correlating the till sheets but no method of correlating the interglacial sands was effected by the methods of investigation utilized in this study.

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CHAPTER I

INTRODUCTION

Purpose of the investigation

In the summer of 1950, the Research Council of Alberta started a survey of Pleistocene deposits in the Edmonton area. The author assisted in this survey and was greatly impressed with the large amounts of sand associated with the glacial deposits in the map area. The summer field work and the materials and information used in this thesis have been assembled under the auspices of the Research Council of Alberta. The kindness of the Council in allowing the use of their equipment, laboratory, working space and materials has aided immeasurably in preparing this thesis.

A survey of literature on the Pleistocene revealed no detailed approach or survey to correlate the sands and tills with in the area. The author will set forth in this thesis the field observations and the results of several analytical methods in an attempt to use the sand, and the sand fraction of the till, to correlate the till sheets and interglacial sands.

Methods of investigation

The methods used in this thesis for correlation are sixfold:

1. Stratigraphic correlation.
2. Mechanical analyses.
3. Histograms.
4. Graphs.
5. Heavy minerals.
6. Sphericity and roundness.

Acknowledgements

The preparation of this thesis has been under the direction of Dr. R. L. Rutherford, Department of Geology, University of Alberta. His criticisms and suggestions have been most helpful.

Thanks are also extended to the other members of the Department of Geology for their aid and criticisms.

W.H.A. Clow, Assistant Geologist, Research Council of Alberta, has given freely in both time and assistance.

Location, boundaries and access

The Edmonton map-area designated herein is that embraced by Sectional Sheet No. 315. It includes townships 49 to 56 and ranges 15 to 27 W. of the fourth meridian, yielding approximately 3920 square miles. The city of Edmonton lies roughly in the west center of the Sectional Sheet.

A network of highways and municipal roads radiating out of Edmonton make most of the area readily accessible by motor vehicle. The only areas which do not permit a detailed examination by normal means of transportation because of few or no roads, are the Indian Reserves, Elk Island National Park, Cooking Lake Forest Reserve and the immediate environs of Ministik, Joseph, Oliver and Miquelon lakes.

Previous work in the area

The earliest mention of the Tertiary and Pleistocene deposits in the area were made by Tyrrell (1886). Dawson (1898) and later Coleman (1909) make further mention of these beds.

Erdtman and Lewis (1931) published a report on their observations of the glacial mantle in the vicinity of Lake Wabamun and three years

years later Taylor (1934) made a survey of the stratigraphy in the vicinity of Edmonton.

Rutherford (1936, 1937) published papers dealing with the Saskatchewan gravels and sands, and later Warren (1937, 1950 a.), Rutherford (1941) and Bretz (1943) published papers dealing with glacial features, deposits and possible correlations.

CHAPTER II

STRATIGRAPHY

General statement

The rocks of the Edmonton area range in age from Upper Cretaceous to Recent. As this report is concerned almost entirely with a correlation of Pleistocene deposits only a brief description of the consolidated strata will be given. These are shown in tabular form on Page 5.

The Upper Cretaceous rocks are dominantly sandstones, somewhat bentonitic, with minor amounts of shale and some coal seams. The Edmonton formation directly underlies the glacial mantle over the greater part of the map-area.

The Tertiary rocks in the area overlie the erosional plain of the Upper Cretaceous and are composed of the Saskatchewan sands and gravels.

Pleistocene and Recent deposits form the covering mantle over almost all the area and are composed of sands, till, silts, laking clays and gravels. The soil mantle in the area grades from a few inches to about five feet.

MESOZOIC FORMATIONS

UPPER CRETACEOUS

Grizzly Bear formation

The Grizzly Bear is found only in the extreme north-east corner of the map-area. The formation consists of dark blue to gray bentonitic shales, which in some places are sandy.

TABLE OF FORMATIONS

Group	System	Series	Formation	Character
Cenozoic	Quaternary	Recent		soils and laking
		Pleistocene	Silt till	light buff to brown, locally stony, till
			Upper Inter-glacial stage	sands, silts, varved clays
			Brown till	buff brown, stony, columnar till
			Lower Inter-glacial stage	green brown to buff brown sands, peat, gravels
			Gray till	gray, coaly, somewhat stony
	Tertiary		Saskatchewan Gravels and Sands	gravel and sand
Mesozoic	Cretaceous	Upper Cretaceous	Edmonton formation	sandstone, bentonitic shale, coal seams
			Bearpaw formation	clay, sandstone, ironstone nodules, some black quartzite and chert pebble conglomerate
			Pale and Variegated beds	light and dark shale, sandstones and coal seams
			Birch Lake formation	buff sandstone and some shale
			Grizzly Bear formation	dark shale and sandy shale

Birch Lake formation

The Birch Lake, like the Grizzly Bear, is found only in the extreme north-east corner of the area. The formation consists of massive gray to buff sandstone with minor amounts of shale.

Pale and Variegated beds (Belly River)

The Pale and Variegated beds cover roughly the area east of a line through Holden and Gibbons. The area occupied by these beds is generally speaking quite flat. They consist of light and dark coloured shales, bentonitic arenaceous shales, pale incoherent sandstones and thin coal seams.

Bearpaw formation

The Bearpaw in the map-area is quite thin and in surface map expression is about two to three miles wide. It consists of light and dark coloured clays with thin beds of sandstone. Ironstone nodules are common and in places a black chert and quartzitic conglomerate is found.

Edmonton formation

The Edmonton is the consolidated strata immediately underlying the till over the remainder of the map-area, and consists of buff, gray and green sandstones, dark bentonitic shales and coal seams.

CENOZOIC FORMATIONS

General statement

The deposits of the Cenozoic are of chief interest in this thesis and a more detailed description will of necessity follow.

The section shwon as Figure 1 is the type section in the area and has been used for correlation purposes. Location of this type section, known as the "Big Bend" section, is Lsd.1 Sec.11 Tp.52 R.25 W4. The outcrop of this section is very complete in detail.

TERTIARY

Saskatchewan gravels and sands

These sands and gravels are quite widespread over the province and good sections of them are exposed in the Edmonton area. They may be observed in the Saskatchewan River valley or in some of the local gravel pits. According to Rutherford (1936), "In the district immediately adjacent to Edmonton along the Saskatchewan valley to the west of the city the sands are the more prevalent material, whereas to the east of the city and in several places somewhat removed from the city gravels are more prevalent."

The Saskatchewan sands and gravels are thought to represent Tertiary deposits as they overlie bedrock and underlie glacial material.

The coarse materials of the gravels are composed of undecomposed bedrock (of local derivation) and pebbles and boulders from the Cordilleran area. These western pebbles are largely chert, quartzitic sandstones and arkosic sandstones. The beds also carry find gold which is most abundant near the base of the gravels.

PLEISTOCENE

Gray till

This is the oldest till observed in the area and is generally found overlying the Saskatchewan sands and gravels. This till is observed only in low places and it appears a long erosional period followed the retreat of the glacier that laid down this deposit.

This till is gray coloured, quite thin and not very stony. The pebbles average about two inches in diameter. When dry, the till has a gray-white colour, and on fresh exposure is black, tough, and of a somewhat fissile nature.

Lower Interglacial stage

Overlying the Gray till in some places is a sand or peat layer that separates the lower Gray till from the overlying Brown till. This is not always present and if missing makes the separation of the Gray and Brown tills quite difficult.

The sands are clear, clean, buff, yellowish to greenish black. They have a prevailingly yellowish brown to buff colour and once seen are easily recognized elsewhere. Gravels have been observed in the sand though they are not common.

Peat (Clow, 1951) and lemming teeth have been found in these beds and are further proof of an interglacial stage. The term stage is here used to indicate a time break between the Gray and Brown tills.

Brown till

This till overlies the Lower Interglacial beds and the Gray till and is quite thick, sections up to 33 feet having been observed. It is brown, massive, very stony, and boulders up to twenty five inches in diameter were observed. When dry it has a light brown colour and weathers into a columnar wall (Figure 2). When wet or on fresh surface the till is sticky and pliable.

Upper Interglacial stage

Beds assigned to this stage include deposits from loess-like material to gravels. There are lake silts, clays, varved clays, sands and sand and gravel pockets and stringers. These deposits lie above the Brown till and where applicable below the Silt till. Some of the sands are not covered and appear to be represented by recent sand dunes.

The sands are wind deposited, waterlain, glacio-fluvial and predominantly gray-green to light brown in colour. The silts are a buff colour showing some bedding features and appear to be both aeolian and waterlain. The laking material is composed of brown clays and varved clays. Locally the brown clays show salt crystals.

There appears to be a threefold division, two sands with an intervening bed of silt or laking material, comprising these deposits. Outcrops showed all variations ranging from no interglacial beds through to the complete sequence. In the majority of outcrops the upper sand was missing and only the two lower phases were present.

Lemming teeth were found in the sands and give weight to interpretation as an interglacial stage. Further evidence toward the possibility of an interglacial period is the persistence of a zone of rhizoconcretions found in the silt phase of these Upper Interglacial beds. These rhizoconcretions are well exposed, in the map-area, at the Acme Brick Company clay pit (Lsd.3 Sec.27 Tp.53 R.25 W4.). Rhizoconcretions are discussed in detail by Kindle (1923) and Rousseau (1934).

The term stage is applied here with the same reservations as for the Lower Interglacial beds, only in this case as a time break between Brown till and Silt till.

Silt till

This till represents the latest glaciation in the map-area. The term "Silt till" is used here for the till overlying the Brown till and Upper Interglacial beds.

The Silt till is quite variable in texture with very few cobbles or pebbles present. It is generally brown to light brown in colour, soft crumbly texture and can easily be mistaken for the Brown till. The lack of stones, softer texture, and siltier nature tend to aid in differentiating this Silt till from the Brown. The presence of Upper Interglacial beds is the best criterion for establishing its identity as can be seen in Figures 3 and 4, where the Silt till overlies sand and varved clays.

RECENT

Deposits of Recent age form the covering mantle of the area. They are represented by soils, swamp muck, peat swamps and some river gravels and sands. The soils, which are the most significant of these Recent deposits, have all formed on the young unconsolidated deposits of drift and have a profile of a few inches to about five feet.

CHAPTER III

METHODS OF INVESTIGATION

STRATIGRAPHIC CORRELATION

General statement

The deposits described in this thesis are assembled in tabular form showing specimen number, location and stratigraphic relationship of the deposit to overlying or underlying beds. They appear in Appendix "A", Tables 1 to 6 inclusive.

Procedure

The placing of the deposits into the proper position in the geologic column was done at the outcrop. All specimens were thus placed on the basis of their correlated position with the "Big Bend" type section.

The assignment of the Saskatchewan gravels and sands was very readily done since in almost every case bedrock was observed below these deposits. When bedrock was not seen the position of these gravels and sands under the Gray till established their stratigraphical position.

The Gray till was readily assigned to its proper position on the basis of its distinguishing colour, the overlying buff coloured interglacial sands and the underlying Saskatchewan gravels and sands.

The Lower Interglacial beds were accurately placed on the basis of their position between the lower Gray till and the upper Brown till. The colour was also an aid in their identification.

The stratigraphic placement of the Brown till was more difficult. Confusion as to whether Brown till, Silt till, or both were exposed was the major enigma in determining this till since on casual appearance the Silt till is easily mistaken for the Brown till. The harder texture, somewhat columnar habit and greater number of cobbles and pebbles of the Brown till were the chief means of separating these two tills.

The assignment of an accurate stratigraphic position to the beds of the Upper Interglacial stage was not readily executed. Sands lie on the Gray till and also under the Silt till. Interbedded between the two sands are a group of silts, clays, varved clays and loess-like material. As previously mentioned, one, any or all of this series may be missing and thus cause confusion. Above the lower sand and in the silt there is a zone of rhizonconcretions which not only aided in fixing the position of the lower sand but also established the presence of the laking silts. If no underlying beds were observed then any sand in the Upper Interglacial stage group was considered to be only of Upper Interglacial stage age and stratigraphically immediately below the Silt till.

The Silt till was, in almost every case, easily assigned to its proper place. This till lies above all other deposits in the area and hence with the soil forms the surface mantle. Some difficulty was encountered when the till was observed but lacked the pebbles or cobbles. A detailed search would always reveal the presence of such pebbles or cobbles and hence establish the outcrop as being that of the Silt till. The softer texture and the lesser number of cobbles and pebbles of the Silt till were the deciding factors in establishing its presence.

MECHANICAL ANALYSES

General statement

Screen analyses were carried out on the sand fractions of seventy samples of sands and tills. Of these seventy analyses two were on bedrock, one on a sand within the Gray till, fourteen on tills and the remaining 53 on other sands. The results of these analyses were compiled on a weight percent basis and a cumulative weight percent basis. These two sets of figures in table form appear in Appendix "B", Tables 1 to 6 inclusive.

Procedure

The samples were screened in Tyler Standard 8 inch screens. The mesh size in millimeters and inches of the screens used are as follows:

Mesh # 28	0.0232 inches	0.589 millimeters
35	0.0164 "	0.417 "
48	0.0116 "	0.295 "
65	0.0082 "	0.208 "
100	0.0058 "	0.147 "
150	0.0041 "	0.104 "
200	0.0029 "	0.074 "

The material smaller than the 200 mesh screen was retained as one cut, and is referred to as the "bottoms". The material caught in the 28 mesh screen ranges from 2 mm. to 0.589 mm. and this was also used as one cut. Screens larger than 0.589 mm. (#28 mesh) were not used as the amount of material above this size was in practically all cases negligible.

Dry sand samples were placed in the top of a nest of screens and the entire column was rocked and tapped with the flat of the hand until sieving in the topmost sieve was completed. This sieve was then removed from the column and the process repeated until sieving was completed. This allowed the finer sieves to be worked for a longer period than the coarser and the critical sieve to be open to view at all times.

Consolidated samples of bedrock and till were placed in a beaker and allowed to soak in water until they were entirely disaggregated. The entire sample was then placed in the top of the nest of sieves and washed through by water. Each sieve was then washed separately to remove any further traces of clay and silt that might have adhered to the sands. The screens, with their sand cuts, were then dried and the sand run through the sieves again as described in the above paragraph for dry sand samples.

When available 500 gram samples of sand and 300 gram samples of till or bedrock were treated. Any specimen not computed from 500 or from 300 grams is specified at the bottom of the column of figures and the weight of the sample used is shown in brackets.

The usage of such large samples somewhat aided in reducing any error caused by loss of sand in the sieves. In a 500 gram sample these losses ran to an average of about 1.87 grams, with a maximum of 4.0 grams and a minimum of 0.2 grams. The use of the large sample made the loss of sand such a small fraction of the total that the loss did not visibly affect any one screen size cut.

The conversion from actual weight to a weight percentage is of slide rule accuracy.

HISTOGRAMS

General statement

Histograms were constructed using the data obtained from mechanical analyses. These histograms appear in Appendix "C", Tables 1 to 6 inclusive.

Procedure

The results of each screen analysis were compiled into a frequency table using the Tyler mesh number as the class intervals, and the frequency of each class grade as a percentage of the total weight. The Tyler mesh number was chosen as the independent variable and the frequency as the dependent variable.

Each grade size (Tyler mesh number) was indicated as of equal width along the horizontal "x" axis. This in effect gives each rectangle an equal width and hence indirectly transforms this scale to a logarithmic scale (Krumbein & Pettijohn 1938, p. 186). The vertical "y" axis represents the weight percentage of the total weight of the sample.

The data from the mechanical analyses was then plotted on histogram tables and assembled into six groups on the basis of stratigraphic position. An exception to this was the grouping of the two types of Upper Interglacial sands on the basis of histogram shape directly. This accounts for the irregularity of stratigraphic position noted in Tables 4 and 5 of Appendix "A".

GRAPHS

General statement

Two types of curves, cumulative frequency and the frequency, were prepared from data obtained from mechanical analyses. Each

curve is placed under the corresponding histogram in Appendix "C", Tables 1 to 6 inclusive. As two distinct types of curves were prepared each will be discussed as a separate entity although both types are placed in the same table.

Procedure

The cumulative frequency curve is one based on histogram data. It is made by plotting ordinates which represent the total amount of material larger than a given diameter. They are equivalent to setting one histogram block above and to the right of the preceding block so that the base of each block is the total height of all preceding blocks. A size scale of Tyler mesh number was chosen as the scale along the horizontal "x" axis and a frequency scale from 0 to 100 percent along the vertical "y" axis. The horizontal scale, as in histograms, is logarithmic. The data from the cumulative weight percent tables in Appendix "B", Tables 1 to 6 inclusive was then plotted as a series of points. These points were then connected to form a smoothed curve yielding a line representing the continuous distribution of sizes.

The frequency curve is a smooth curve showing the variation of the dependent variable as a continuous function of the independent variable. There is a relationship between cumulative curves, frequency curves, and histograms, but in the construction of such curves from histogram data the cumulative curve is most convenient. The relationship between the histogram and the frequency curve is that the latter denotes the limit of a histogram as each class limit becomes smaller and finally reaches zero, while the frequency increases without bound. In the construction of these frequency curves a smooth continuous curve was simply superimposed over the histogram bars.

HEAVY MINERAL ANALYSES

General statement

The heavy minerals were separated, examined microscopically and the results placed into table form, showing the frequency of occurrence of individual species and the persistence of each species. The compilation of these results are in Appendix "D", Tables 1 to 6 inclusive.

Procedure

The separation of the heavy minerals from the sand was carried out by the bromoform method as described in the Manual of Sedimentary Petrography, pp. 343-344 (Krumbein and Pettijohn, 1938).

In each analyses 25 grams of the sand were placed in the bromoform and each sample allowed to stand for a period of one hour. Each sample was thoroughly stirred upon being placed in the bromoform and subsequently every ten minutes thereafter.

The heavy mineral residue deposited on the filter paper was washed with acetone and dried.

An immersion mount of the heavy mineral suite was prepared in ortho-nitro-toluene (index of refraction 1.5442) and this mount placed under the petrographic microscope for examination of the individual mineral species.

The individual grains were examined and determined using the Manual of Sedimentary Petrography (Krumbein and Pettijohn, 1938), An Introduction to Sedimentary Petrography (Milner, 1922) and Optical Mineralogy (Rogers and Kerr, 1942) which proved to be very good and concise aids. The frequency of occurrence of

each mineral was also noted on the basis of the scale set up by Milner (1922). This table, partially reproduced below, gives only a simple estimation by eye. No attempt was made to make an individual count of the grains.

Table after Milner

TERM	SYMBOL
Flood	F
Very abundant	A
Abundant	a
Very common	C
Common	c
Scarce	s
Very scarce	S
Rare	r
Very rare	R

Some animal teeth, probably those of lemmings, were observed and noted in the heavy mineral suite. These were identified and confirmed by Stelck (1951). The presence of teeth and the appropriate specimen number is noted below the table, where applicable.

SPHERICITY AND ROUNDNESS

General statement

Selected samples of sands were photographed and from these photographs sphericity and roundness values were obtained. The results of these computations appear in Appendix "E", Tables 1 to 7 inclusive.

Procedure

Representative specimens of the sand were chosen and immersion mounts made of the sand grains. The medium used for making these wet mounts was alpha-monochlornapthalene (index of refraction 1.626) allowing the quartz grains, in particular, to stand out with good relief.

These slides were then placed under a petrographic microscope with medium power magnification (x 80). The microscope was placed under a "Leitz M.A.4 B. Camera Photographic Apparatus" with a 120 film adaptor. 120 verichrome film was used with an exposure time of 3 seconds. A magnification of 125 times was obtained from this method and one photomicrograph of each representative sand type was taken.

Two specimens from each of the six groups in Appendix "A" were photographed in the above manner and from these photographs sphericity and roundness data were obtained.

Two-dimensional sphericities were rapidly made from a table devised by Rittenhouse (1946). This visual comparison chart prepared by Rittenhouse is reproduced here (Figure 6). In order to check results the author had four unbiased comparisons of the sphericities made by classmates. The results of their work and that of the author were remarkably similar in all cases.

The compilation of the roundness data required considerable time. Circles with radii from 1 mm. to 16 mm. were described on a piece of tracing cloth. This was then placed on the picture of the sand grain in question and the required radius determined. The roundness factors were obtained from using the formula:

$$P\ (\text{rho}) = \frac{(r_i/R)}{N}$$

where r_i = individual radii of corners

N = number of corners

R = radius of the maximum inscribed circle

CHAPTER IV

INTERPRETATION

STRATIGRAPHIC CORRELATION

Stratigraphic correlation was found to be an effective method of identifying the deposit and delineating the areal distribution of the deposit.

Saskatchewan sands and gravels

These sands and gravels were traced by the author as far west as Seba Beach, but were not observed east of the eastern boundary range 22 within the map-area. The sands and gravels are not limited to the valleys but appear throughout the map-area at elevations ranging from 2000 feet to 2310 feet above sea level. However the thickest deposits were observed in the Saskatchewan River valley.

The top of these deposits was used as the lowermost boundary of the Pleistocene in the map-area. The gravels showed every indication of being river transported and the lack of Precambrian boulders, cobbles and pebbles suggests a western source probably in the Cordilleran.

Gray till

This Gray till lying above the Saskatchewan gravels and sands and below the Brown till was very readily distinguished in the map-area. Gray till was observed at such places as Tofield, Cardiff, Devon, west of the map-area at Lake Wabamun and also south at Labuma on the Red Deer river. The till appears to have, at one

time, covered the entire Edmonton area and it represents the first glaciation over this area. The abundance of granites, gneisses and schists from the Precambrian establishes the till as having an eastern source and undoubtedly being a phase of the Laurentide ice-sheet.

Gray till was observed in only the topographically low places. In no place was the till exceedingly thick reaching an observed maximum of only 12 feet. Erosional features are common on the till surface and it is assumed a strong period of erosion took place after the deposition of this Gray till. Channels and gouges were scoured out and filled by later deposits, and at the west end of the Edmonton Golf and Country Club on the north bank of the river it may be seen where the finer fractions of the till have been completely eroded out leaving only the gravel. This erosional period left the Gray till scattered throughout the country in the form of isolated patches.

Lower Interglacial beds

These beds are present over most of the map-area and were observed at many places including Tofield, Mearns, Elk Island Park, Devon and Fort Saskatchewan. They are generally represented by a buff light coloured, clean, bedded and cross-bedded sand. Locally the sands were dirty and had some coarser pebble and cobble phases present and at one locality (Lsd. 14 Sec. 36 Tp. 56 R. 26 W. 4) a peat bed was observed. Peat, which represents the first stage in coal formation, is formed from the accumulation of grasses, sphagnum, and other plants in moist places. This peat layer is the first recorded occurence at this stratigraphic position in the province.

The peat was dark brown to black in colour with some fibrous material and locally quite compact.

The sands, probably in part derived from Gray till erosion, which fill the old erosional pockets and gulleys appear to be stream and in part wind deposited. The peat which developed in the low areas of the region indicates a time of plant growth and a possible rise of mean average temperature. These two deposits indicate a long period of erosion following the deposition of the Gray till and an interglacial period of a considerable time.

Brown till

The Brown till, lying unconformably on Lower Interglacial beds or Gray till, was present over the entire map-area. This till has considerably greater numbers of the Precambrian clastics and like the Gray till had its source on the Canadian Shield, probably associated with the Laurentide ice movement.

Brown till outcrop, observed in the map-area is considerably thicker than the Gray till but it has been subjected to erosion, either partially or completely, and is covered by later deposits. It has an observed maximum thickness of 33 feet and is more prevalent than the Gray till.

This till displays a typical columnar habit and in many places the lower part of the till sheet appears to be bedded. In some of the observed sections the middle of the till has gravel and sand stringers and in nearly all cases the upper part of the till sheet is eroded and undulatory.

The increased number of boulders, cobbles and pebbles in this till can probably be attributed to the ice passing over the old

erosional plain of the Gray till where these materials would be in abundance, being left from the erosion and washing away of the finer sand phases. The thickness of this Brown till as compared to the Gray can possibly be explained by either a thicker ice advance or a shorter period of erosion. A shorter period of erosion is favoured as the Silt till above, like the Gray till below, has very few cobbles and pebbles present. This Brown till appears to be the product of a separate ice advance on the basis of the lower, separating, inter-glacial beds and the very distinct colour difference from the Gray till. It is difficult to reconcile only one ice advance with such diverse properties in these two till sheets.

Upper Interglacial beds

These beds presented many difficulties and hence a greater number of suppositions must be made. Under this heading the sands at Winterburn, Woodbend, Glory Hills, Redwater and Elk Island Park are tentatively placed and in many places these sands are now at the surface. It is assumed these upper beds are associated with a large lake in the Edmonton area and this can be noted by reference to the glacial map (in folder) accompanying this thesis.

This glacial topography map shows a large flat area in the environs of the city of Edmonton. It is suggested a large proglacial lake occupied this area as is evidenced by the large amounts of clays, varved clays and bedded silts noted in the cutbanks of the Sturgeon and Saskatchewan rivers.

The author postulates that as the glacier responsible for the deposition of the Brown till retreated eastward it halted in the morainal area in the center of the sheet (Cooking Lake Moraine). As the glacier halted here amounts of sand would wash down the front

and out onto the proglacial area. The dammed glacial waters would soon form a large lake and the marginal sands would be shaped into dunes by the winds prevalent in front of the glacier. In the quiet deep water the finer clays, varved clays and bedded silts would be deposited. That the lake level was fluctuating is evidenced by the tiers of rhizonconcretions observed within the silt. Here plant life probably flourished and was then covered and killed by rising or falling waters or local ice advances. As the ice retreated farther eastward this dammed body of water broke through the moraine area in the vicinity of Bruderheim and flowed in back and east of the Cooking Lake moraine, probably removing large amounts of materials. Various erosive forces would then take the old beach and dune sands and distribute them over the lake silts.

Silt till

This till has almost complete coverage over the map-area. It represents the last observed glaciation and is extremely variable in composition, texture and thickness. The only place this till was not recognized or observed was in the areas marked "sand" on the glacial map and in the extreme west of the map-area on top of the Glory Hills.

The evidence supporting this third glaciation is readily observed in the various exposures throughout the area. Figures 3, 4, and 5 all show interglacial beds or features separating the Silt till from the Brown. There was undoubtedly a period of erosion prior to the advance of this third ice sheet but it was of a shorter duration than that of the Lower Interglacial stage. The cross-bedded and bedded sands, underlying varved clays (Figure 4) and the erosional

pebble lines (Figure 5) all give evidence to confirm an interglacial period. Arkosic pebbles typical of the Saskatchewan gravels were also found in this till which suggests erosion had bared these deposits. This is the only till in which such cobbles and pebbles were found.

The author is not prepared to say from which direction this ice-advance came but does recognize the presence of a third glaciation which forms the uppermost glacial deposits over the Edmonton area. The shorter erosional period of the Upper Interglacial period would not permit a large accumulation of pebbles and cobbles to be weathered out on the surface of the Brown till and hence lesser amounts of this coarser material in the Silt till. The large amount of laking clays and silts over which the ice advanced would account for the finer silty nature of the Silt till in the same manner in Deane (1950) accounts for the silty nature of some of the tills in the Lake Simcoe district in Ontario.

MECHANICAL ANALYSES

Interpretation of mechanical analyses

Interpretation from mechanical analyses are usually made from histograms, graphs, etc. However a unique method of direct interpretation from mechanical analyses is that described by Gardescu and Billings (1937) in which serial numbers are used to identify the various screen cuts. These serial numbers are constructed from the screen cuts. The 28 mesh is represented by 1, the 35 mesh by 2, the 48 mesh by 3, etc. To build up a serial number the largest screen cut of an analysis is used as the first digit, the second largest screen cut as the second digit, etc. For example the serial number for specimen a_1 is 3-4-2-5-1-6-7-8. The coarseness index is

arbitrarily chosen as the 65 mesh screen cut and the index for specimen a_1 would be 29.10.

A series of such serial numbers and their corresponding coarseness indexes was prepared for the seventy specimens of this thesis in an attempt to evolve pertinent information for correlation.

The serial numbers for the Saskatchewan sands, Lower Interglacial, Upper Interglacial and Miscellaneous sands were for all practical purpose similar. The only deviation appeared in specimen h_1 of the Saskatchewan sands which was markedly different from the other serial numbers of the sands but remarkably similar to specimens c_6, d_6 and e_6 of the Miscellaneous sands.

All specimens of the till and bedrock revealed similar serial numbers. The sand within the Gray till (specimen c_2) yielded a serial number about one half way between that obtained for the till and that obtained for the Lower Interglacial sands.

Such results indicate that there were at least three sets of environmental conditions. That of the tills is the same, all the Interglacial sands and the Saskatchewan sands are similar and specimens h_1, c_6, d_6 and e_6 represent another set of conditions.

The serial numbers did not reveal any data diagnostic for correlation and the coarseness index number was so variable throughout that no attempt was made to utilize it. There is an indication that the sands of the till were in part derived from the underlying bedrock of the Edmonton formation and the interglacial sands were derived from the till.

HISTOGRAMS

General characteristics of histograms

Udden (1914) found continental tills to be notably uniform in composition with maximum ingredients from 1/16 to 1/32 mm. in diameter. Some of Udden's glacial sands were as well sorted as beach sands while others were very poorly sorted. His beach deposits were all very well sorted with 66% of the sample in the maximum and the entire sample spread over an average of three grades in the histogram. Coarse drifting sands had a predominance (about 50%) in the 1/4 to 1/8 mm. in diameter class while the dune sands has fine sand (1/4 to 1/8 mm. in diameter) as the maximum ingredient (average 65% of the total). These dune sands were remarkably uniform in mechanical composition and had approximately 90% of their distribution among three grades. In all drifted and blown material Udden found the coarse admixtures to be in excess of the fine.

Krumbein (1933) in his work on glacial tills found they had extremely irregular distributions and several secondary maxima rendered them polymodal. He further noted the influence of the immediately underlying bedrock on the mechanical composition was as inconsequential in one till as another. Krumbein did find that a given ice sheet does tend to produce a till that has a fairly well defined frequency distribution.

Doeglas (1946) in his work on Dutch sediments found beach sands have no characteristic size frequency distribution, the shape and size being mainly dependent on the detritus available inland

from the coast. In analyses of aeolian sands he found the size range small, the particles well sorted, symmetrical frequency distribution and that clay particles were wanting.

Interpretation of histograms

Histograms of the size distribution of sands permit a comparison of sands to be easily and readily made. As yet the shape of histograms do not allow a wind deposited sand to be distinguished from a sand of aqueous deposition. All that can be ventured is the suggestion that the shape of the histogram suggests a type of environment.

The histograms, in Table 1, Appendix C, of the Saskatchewan sands are extremely variable. None could be classified as either beach or aeolian sands as defined by Udden (1914). Specimens d_1, e_1, f_1 and g_1 show some similarity and specimen h_1 appears similar to the washed beach sands of Table 6 (specimens c_6, d_6 and e_6). Specimens a_1, b_1 and c_1 show no similarity to each other or to any of the other histograms of the Saskatchewan sands. All of the Saskatchewan sands are well sorted but no correlation by histograms was possible.

Table 2 of Appendix C reveals better results than any of the other five tables. The two histograms of the Edmonton sandstone (specimens a_2 and b_2) show a distinct similarity. The sand is bimodal with about 35% of the sample in the silt-clay fraction.

The histograms of the till sheets are very similar. All are polymodal in agreement with Krumbein (1933) and these tills further show a uniformity of composition and maximum ingredients from 1/16 to 1/32 mm. in diameter which agrees with Udden's (1914) results. A noticeable difference in the percentage of the silt-clay fraction

of each till type is present. The average percentage of these fine cuts is 68.3% for the Gray, 58.2% for the Brown and 65.5% for the Silt till. This feature does present a possible means of correlation but much more work will have to be done before any concrete conclusions may be drawn.

The Lower Interglacial sands of Table 3 show no similar histogram pattern. These sands are, with the exception of specimen h_3 well sorted but their histograms reveal no diagnostic criteria for correlation. There is every indication, on the basis of histogram shape, that the environment of deposition for these sands was the same as for the Upper Interglacial sands.

Tables 4 and 5 of Appendix C show histograms of sands under the Silt till. The majority of the Upper Interglacial sands fitted into one of these two groups. The histogram shape of these sands was the basis for this large two-fold division.

The histograms of Table 4 are all remarkably constant indicating a particular type of deposition for all of these sands. Some of the individual specimens are bimodal but the maximum ingredient is common in every case. Specimen m_3 of Table 3 is very similar to the histograms of this group.

The histogram shapes of the specimens in Table 5 are also very similar. Some of the sands are bimodal but all showed a very marked degree of sorting. Several specimens of Lower Interglacial sands in Table 3 are similar in shape to these histograms and indicate a similar environment of deposition.

The histograms of the Upper Interglacial sands show a predominance of two distinct types of depositional environment but

the histogram shape does not reveal a means of correlating these sands throughout the area or of distinguishing them from the Lower Interglacial sands.

In the Miscellaneous sands of Table 6 specimens a_6 and b_6 from the Upper Interglacial sands appear to be coarser phases of the sands in Tables 4 and 5 respectively. Specimen c_6 is a histogram of a modern beach sand and specimens d_6, e_6 and h_1 are very similar to it. Specimens f_6 and g_6 both of Upper Interglacial age bear no similarity to any other histogram.

A study of the histograms of the sands in this thesis did not allow any of the sands to be established as aeolian or aqueous. The histograms do reveal several environments of deposition were present and that these same environments were probably present during the deposition of the Saskatchewan, Lower and Upper Interglacial sands. The histograms of the till types are very similar and the histograms of tills do present a possible means of correlation.

GRAPHS

General characteristics of graphs

Twenhofel and Tyler (1941) state that the cumulative frequency curve is practically independent of the grade scale used and is a more reliable index of the nature of the distribution of particles in sediments than a histogram or frequency curve. These authors further agree that the mathematical values derived from the cumulative frequency curves better express the character of the sediment than do visual comparative methods.

Trask (1932) prepared the coefficient of sorting from the first and third quartile measurements. This geometrical quartile

measure eliminates the size factor, that is, the difference in coarseness between samples or the units of measurement have no influence on the coefficient of sorting. Trask states that if the coefficient of sorting is less than 2.5 the sample is well sorted, if greater than 4.5 poorly sorted and if about 3.0 normal sorting.

Interpretation of frequency and cumulative frequency curves

The frequency curves were prepared with the view they might reveal certain characteristics the histograms did not, but such was not the case and these frequency curves were less diagnostic than histograms and no correlative data was obtained from them.

The results obtained from the cumulative frequency curves were no more fruitful than those of the simple frequency curves. An attempt to use the coefficient of sorting, derived from the cumulative frequency curves, was also ineffectual for correlation.

The cumulative curves of the Saskatchewan gravels show some similarity and indicate that water washing has removed a greater part of the finer phases. The coefficient of sorting averages about 0.36 with variations from 1.4 to 0.35.

The cumulative curves of the Edmonton formation are very similar and yield a sorting coefficient of 1.86 indicating a lesser degree of sorting than that of the Saskatchewan sands.

The cumulative curves of the till sheets yielded a high sorting value. The average coefficient of sorting was 2.18 but the Brown till gave a slightly lower value probably indicating removal of some of the finer silt-clay phases by water washing prior to deposition. All cumulative curves of the three till sheets are markedly similar but are of no apparent visual value for correlation.

The cumulative curves of the Lower Interglacial sands were of little use for correlation and showed good sorting with an average coefficient of sorting value of 0.36. Specimen h_3 was high with a value of 1.68 for the sorting and merely has a greater amount of silt-clay material present.

The curves of the Upper Interglacial sands (Tables 4 and 5) gave an average sorting value of 0.374 with a very small deviation from this figure. This value is very similar to that obtained for the Saskatchewan sands and the Lower Interglacial sands and merely shows that these three sets of sands are well sorted.

The cumulative curves of the Miscellaneous sands have varying coefficient of sorting values which though close to the values obtained for the Upper Interglacial sands do not allow a correlation of these Miscellaneous sands to any of the Upper Interglacial sands.

No results of any diagnostic value were obtained from frequency curves or cumulative frequency curves. The coefficient of sorting value did show a variation in the degree of sorting but it was not marked enough for correlation purposes.

HEAVY MINERALS

Source of heavy minerals

Pleistocene geologists have long claimed that glacial till is largely of local origin (Flint, 1947: Salisbury, 1900). Wallace and McCartney (1928) working with Pleistocene sands in Manitoba and Saskatchewan attributed their Pleistocene sands to direct derivation from the Precambrian. Later Krumbein (1933) working with tills showed that the heavy minerals found in the tills were largely derived from crystalline sources and he inferred this from the abundance of

hornblende present. Studies of the till sheets in Minnesota by Kruger (1937) showed that the heavy minerals were from granitic type rocks and Rittenhouse (1946) asserts the type of mineral present is indicative of the source. Work on fluvio-glacial sands in New Zealand by Hutton (1950) showed the type of heavy mineral present was of a granitic source. Gravenor (1951) working with tills in southwestern Ontario found his results coincided with those of Kruger, the heavy mineral suite showed no appreciable variation, and hence a granitic rock type source from the Precambrian. All of these studies were made where the tills are relatively close to the Precambrian shield.

Interpretation of heavy mineral analyses

Correlation of deposits by means of their petrology must necessarily presuppose that they all contain a common but distinctive mineral assemblage. Solomon (1932) and Rittenhouse (1946) both used this method of correlation successfully but found it time consuming, exacting and exhaustive. The heavy minerals from certain strata are distinct and are also a very useful guide to the source rock of the deposit. Boswell (1933) and Pettijohn (1941) both agree that there is an apparent increase in the complexity of heavy mineral assemblage with decreasing geologic age, which can be attributed to the greater complexity of new terrane and the disappearance by solution of the less stable minerals in the older. However, the actual mineral assemblage is a function of both the source rock and the mineral stability.

Various workers have arrived at some general conclusions regarding actual minerals present in deposits. Wallace and McCartney (1928) suggested the presence of abundant hornblende in their Pleistocene sands indicated very limited weathering. The presence of apatite suggests a low percentage of CO_2 in the atmosphere and cool conditions (Boswell, 1933). Rubey (1933) found that the coarsest grained and finest grained samples of Pleistocene sands, both from the same till body, differed in heavy mineral assemblages. In the coarse he found epidote, kyanite, andalusite, rutile and hypersthene while in the fine sands magnetite, ilmenite, zircon, muscovite and biotite were the major constituents. Russell (1937) put forth the suggestion that feldspars, pyroxenes and amphiboles are very susceptible to abrasive action whereas rutile, ziroon, and tourmaline are very resistant. Russell further stated that limonite cannot be transported any great distance from its source area. A list prepared by Dryden and Dryden (1946) showing the order of stability is as follows:

1. zircon
2. tourmaline
3. sillimanite
4. monazite
5. chloritoid
6. kyanite
7. hornblende
8. staurolite
9. garnet
10. hypersthene

Rittenhouse (LeRoy and Crain, 1949) lists andalusite, kyanite, staurolite and sillimanite as being originally derived from metamorphic rocks while rutile, zircon, ilmenite, apatite, olivine, titanite and tourmaline (?) indicative of an igneous source. Hutton (1950) states that the presence of zircon, garnet and hornblende in glacial sands point to a granitic source.

A study of the tables in Appendix D reveal that certain generalizations and conclusions discussed in the above paragraphs are applicable to heavy mineral suites of the Pleistocene deposits in the Edmonton area.

The heavy mineral suite under specimen a_2, Table 2, is that of the Edmonton formation which shows a complete lack of the amphibole group and only minor amounts of garnet. This indicates long weathering and perhaps a certain amount of recycling, allowing the beds to be differentiated from all sands above the Edmonton formation. There is no reflection of its heavy mineral suite in the sands above.

Table 1 of the Saskatchewan gravels reveals an abundance of amphibole and garnet groups, a scarcity of apatite and in general a lesser variety of heavy mineral assemblage than the overlying glacial tills and sands but a greater variety than the underlying Edmonton sandstone. The complex heavy mineral content indicates a younger and more complex source for the gravels than for the Edmonton sandstone and a younger age for the Saskatchewan gravels because of the presence of the less stable minerals.

Table 2 which constitutes the heavy mineral analyses of the three till sheets in the map-area shows abundant amounts of amphibole, garnet and limonite. There is a persistence of apatite, chlorite, ilmenite, leucoxene, magnetite, staurolite and zircon. The absence of haematite in the Gray till, muscovite in the Gray and Silt tills and tourmaline in the Brown till are indicative of a means of correlation. However the rarity or absence of haematite, muscovite and tourmaline in all samples rather precludes these minerals as a diagnostic criterion for correlation. Heavy minerals present in these

till sheets indicate an igneous and metamorphic source from the Precambrian shield, a young age, fine to coarse sands, cool climate, limited weathering and the formation of limonite locally. The presence of the amphiboles and their relation to limited abrasive action as suggested by Russell (1937) is doubted.

Table 3 of the Lower Interglacial sands evinces an abundance of amphiboles, garnets and limonite, a persistence of apatite, haematite, ilmenite, leucoxene, magnetite and staurolite and a noticeable absence of tourmaline. There is no detrital in this groups not represented in the underlying till and all indications point to a derivation of these sands from this Gray till. The lemming teeth found in the heavy mineral residue of these sands point to the presence of an interglacial stage.

Tables 4 and 5, of the Upper Interglacial sands, both reveal an abundance of the amphibole, garnet and limonite groups while apatite, ilmenite, leucoxene, magnetite and staurolite show a persistence throughout. There is, again, a complete lack of tourmaline which is to be expected here as none was observed in the Brown till. All minerals present in this Upper Interglacial detrital group appear to be a reflection of the Brown till from which these sands are derived. Lemming teeth, also observed in heavy mineral suites from these beds, indicate an interglacial period.

The miscellaneous sands of Table 6 reveal the same detrital groups that prevail throughout the other heavy mineral assemblages. Hence these sands are assumed to have the glacial tills in the area as their source.

The heavy mineral suites from Pleistocene sands and tills of the map-area are indicative of a granitic and metamorphic source

which is undoubtedly the Precambrian shield. These detrital assemblages show no reflection to the underlying Edmonton sandstone and the presence of abundant hornblende and garnet indicates a younger age for these deposits than the underlying bedrock. The heavy mineral analyses revealed no diagnostic criterion for correlation of the Pleistocene till sheets or sands.

SPHERICITY AND ROUNDNESS

Factors controlling sphericity and roundness

Wadell (1932) pointed out that sphericity (shape) and roundness are independent properties of sedimentary particles. It was later shown by Fraser (1935) that certain minerals break up more readily than others and are unable to stand the vigorous wear necessary to round them, and they become smaller without becoming rounded. Work on Mississippi river sands by Russell and Taylor (1937) revealed particles as small as 0.05 mm. in diameter can be rounded by water and that there is a decrease in sphericity and roundness with a decrease in grain size. Krumbein (1941) found roundness to be strongly modified by abrasion and wear to which particles are subjected, whereas shape may play its most important role in the selective transportation of the particle. Abrasion rapidly modifies the roundness but after the initial stages of rounding the process is much slower. Work by Alling (1950) led to the conclusion that with the exception of slight modification produced by abrasion the end shape of a sand grain appears to be determined by its original shape.

Wadell (1933) attributed the following four factors as responsible for shape: different cohesive forces in different

directions, the mode of crushing, grinding and direct blows and, crystal structure. A later list put forth by Krumbein and Pettijohn (1938) is as follows: original shape, structure (cleavage, bedding, etc.), durability, nature of the geologic agent, nature of action and violence of action, and, the time or distance over which the action is extended.

The above paragraphs reveal there is such a great number of geologic features involved in the development of sphericity and roundness that any one criterion based on a single principle is likely to be unreliable.

Interpretation of sphericity-roundness data

Correlation by sphericity-roundness data using an arbitrary set of standards is possible (Wadell, 1932). Appalachian oil producing sands were correlated with sphericity-roundness measurements by Rittenhouse (1946), where roundness was established as an independent criterion (used with caution) for outlining types of sediments. LeRoy (LeRoy and Crain, 1949) also asserts these sphericity-roundness measurements have served in correlating certain strata.

Pettijohn (1949) infers that the evaluations listed below can be interpreted from sphericity-roundness data:

1. roundness is a good index to the maturity of a sediment.
2. prolonged abrasion will modify the sphericity.
3. where the sediment is not derived from pre-existing sediments, and where it has been little transported, all particles have the same or nearly the same roundness.

From the results shown in Appendix "E" the average sphericity value obtained for the Edmonton sandstone was considerably higher

than that of the Saskatchewan sands and precludes any relationship between these two beds. There is, however, a striking increase from the value of 0.753 for the Saskatchewan sands to that of 0.877 for the Silt till. The average sphericity value increases for each overlying bed and suggests the Saskatchewan sands as a major source of local material for the first ice advance. The sands picked up by the Gray till would be modified and yield a higher average sphericity value. The sands eroded out of the Gray till would be further modified by geologic agents acting on them and thus yield the higher value obtained for the Lower Interglacial sands. This repeated usage of the original sand would explain the increasing sphericity with decreasing geologic age.

An average sphericity value of 0.799 obtained for the Upper Interglacial sands disrupts the continuity of the increasing sphericity. The reasons for this aberration are many and detailed inquiry into this problem would undoubtedly solve it. Regardless of this anomalous average sphericity figure for the Upper Interglacial beds it is assumed they supplied abundant local material for the Silt till.

The average sphericity results with the above exception, show an increasing sphericity with decreasing geologic age and support the assumption that source materials for the glacial tills in the Edmonton area are largely of local origin. These sphericity measurements exhibit a possible means of correlating till bodies but more detailed work on a larger scale attempt is necessary to establish definite conclusions.

For comparative purposes the roundness data is classified on Pettijohn's scale (1949) partially reproduced below:

Grade term	Class limits	Geometric mid-point
angular	0 to 0.15	0.125
subangular	0.15 to 0.25	0.200
subrounded	0.25 to 0.40	0.315
rounded	0.40 to 0.60	0.500
well rounded	0.60 to 1.00	0.800

The average roundness factor for the seven sands in Appendix "E" yielded a figure of 0.451. The maximum deviation from this was found in the Brown till which gave a roundness factor of 0.386. This average roundness factor places these sands in the lower class limits of Pettijohns rounded grade but the roundness factor of the individual grains range from subangular to well rounded.

There is a large difference in values obtained for the Edmonton sandstone and the Saskatchewan sands. Also, the Gray and Brown tills have roundness factors close to that of the Edmonton formation which may indicate an association. The varying roundness factors do show abrasion modifies the roundness but do not reveal any broad diagnostic differences that can be noted.

Sphericity-roundness data of the sands under discussion in this thesis revealed no absolute means of correlation. The sphericity factor presented a possibility for correlation but no diagnostic features can as yet be assumed. Roundness data offered no interpretative evaluations that were of use in correlation. The rounded classification of the sands revealed a certain amount of maturity and it may be

interpreted that prolonged abrasion modifies the sphericity. These sphericity-roundness values do show that sphericity (shape) and roundness are independent properties of sedimentary particles.

CHAPTER V

SUMMARY AND CONCLUSIONS

The study of the Pleistocene deposits in the Edmonton area has revealed the presence of three separate glacial tills and two separate interglacial beds. The presence of the three till sheets is confirmed by a stratigraphic study, histograms and sphericity-roundness data. An abundance of boulders, cobbles and pebbles of the Precambrian type indicate association of these ice advances to the Laurentide ice-sheet and the heavy mineral analyses show abundant minerals derived from igneous and metamorphic rocks further confirming the Canadian Shield as the source of the icesheets. There is every indication from the results of stratigraphic studies, sphericity-roundness data and mechanical analyses that the advancing ice used both Edmonton sandstone and Saskatchewan sands as local source material in the formation of the till.

The occurrence of peat in the Lower Interglacial beds, rhizoconcretions in the Upper Interglacial beds and the presence of lemming teeth in both beds indicates the ice retreated to the extent of allowing life to exist in this area during these interglacial stages.

The mechanical analysis of each till type yielded a characteristic curve and histogram. The interglacial sands while not yielding characteristic histograms, curves and mechanical analyses do show certain depositional environments were present in each stage and that these same environments were present in both stages.

The sand fraction of the underlying till appears to be the main source of the corresponding overlying interglacial sand and this interglacial sand supplied a local source of material for the next ice advance. The stratigraphic study, heavy minerals, sphericity-roundness data and mechanical analyses all support this supposition.

Very meager results were obtained from the six methods of investigation used in this thesis in an attempt to correlate the sands and tills of Pleistocene age in the Edmonton area. Some of the interpretations and results agree with the findings of other workers and certain inferences may be made from some of this data. No absolute method of correlating the sands and tills of Pleistocene age in the Edmonton map-area was evolved from the methods of study used in this thesis.

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BIBLIOGRAPHY

Alling, H.L. (1950): Initial shape and roundness of sedimentary rock mineral particles of sand size; Jour. Sedim. Pet., Vol. 20, No. 3.

Boswell, P.G.H. (1933): On the mineralogy of sedimentary rocks; T. Murby and Co., London.

Bretz, J.H. (1943): Keewatin end moraines in Alberta, Canada; Bull., Geol. Soc. Am., Vol. 54.

Clow, W.H.A. (1951): Unpublished report on the Pleistocene geology of the Edmonton Area; Res. Counc. of Alberta.

Coleman, A.P. (1909): The drift of Alberta and the relations of the Cordilleran and Keewatin ice sheets; Roy. Soc. Can., Trans. Vol. 3.

Dawson, G.M. (1898): Geol. Surv., Canada, Sum. Rept. Pt. A, Vol. 11.

Deane, R.E. (1950): Pleistocene geology of the Lake Simcoe district, Ontario; Geol. Surv., Canada, Memoir 256.

Doeglas, D.J. (1946): Interpretation of the results of mechanical analyses; Jour. Sedim, Pet., Vol. 16, No. 3.

Dryden, L. and Dryden, C. (1946): Comparitive rates of weathering of some common heavy minerals; Jour. Sedim. Pet., Vol. 16, No. 3.

Erdtman, G. and Lewis, F.J. (1931): A section through the glacial drift near Wabamun Lake, Alberta, Canada; Zeitschrift fur Gletscherkunde, BD. XIX, Heft 1/3.

Flint, R.F. (1947): Glacial geology and the Pleistocene epoch; J. Wiley and Son, New York.

Fraser, H.J. (1935): Experimental study of the porosity and permeability of clastic sediments; Jour. Geol., Vol. 43, No. 8.

Gardescu, I.I. and Billings, M.H. (1937): Use of mechanical sand analyses for correlation purposes; Bull., Am. Assn. Pet. Geol., Vol. 21, No. 10.

Gravenor, C.P. (1951): Bedrock source of tills in southwestern Ontario; Am. Jour. Sci., Vol. 249, No. 1.

Hutton, C.O. (1950): Studies of heavy detrital minerals; Bull., Geol. Soc. Am., Vol. 61, No. 7.

Kindle, E.M. (1923): Range and distribution of certain types of Canadian Pleistocene concretions; Bull., Geol. Soc. Am., Vol. 34.

Kruger, F.C. (1937): A sedimentary and petrographic study of certain glacial drifts of Minnesota; Am. Jour. Sci., Vol. 34, 5th Series.

Krumbein, W.C. (1933): Textural and lithological variations in glacial till; Jour. Geol., Vol. 41, No. 4.

----- and Pettijohn, F.J. (1938): Manual of sedimentary petrography; Appleton, Century, Crofts Inc., New York.

----- (1941): Measurement and geological significance of shape and roundness of sedimentary particles; Jour. Sedim. Pet., Vol. 11, No. 2.

LeRoy, L.W. and Crain, H.M. (1949): Subsurface geologic methods; Colo. School Mines, Golden, Colo.

Milner, H.B. (1922): An introduction to sedimentary petrography; T. Murby and Co., London.

Pettijohn, F.J. (1941): Persistence of heavy minerals and geologic age; Jour. Geol., Vol. 49, No. 6.

----- (1949): Sedimentary rocks; Harper and Bros., New York.

Rittenhouse, G. (1943 a): A visual method of estimating two dimensional sphericity; Jour. Sedim. Pet., Vol. 13, No. 2.

----- (1943 b): Transportation and deposition of heavy minerals; Bull., Geol. Soc. Am., Vol. 54.

----- (1946): Grain roundness - a valuable geologic tool; Bull. Am. Assn. Pet. Geol., Vol. 30, No. 7.

Rogers, A.F. and Kerr, P.F. (1942): Optical mineralogy; McGraw Hill Co., New York.

Rousseau, J. (1934): The part played by some tidal plants in the formation of clay rhizoconcretions; Jour. Sedim. Pet., Vol. 4, No. 2.

Rubey, W.W. (1933): The size distribution of heavy minerals within a water-laid sandstone; Jour. Sedim. Pet., Vol. 3, No. 1.

Russell, R.D. (1937): Mineral composition of Mississippi river sands; Bull., Geol. Soc. Am., Vol. 48.

----- and Taylor, R.E. (1937): Roundness and shape of Mississippi river sands; Jour. Geol., Vol. 45, No. 3.

Rutherford, R.L. (1936): Some gravels and sands in the Edmonton district, Alberta; Geol. Surv., Canada, Prelim. Rept., 36 - 22.

Rutherford, R.L. (1937): Saskatchewan gravels and sands in central Alberta; Roy. Soc. Can., Trans., Vol. 31, Sec. 4.

----- (1941): Some aspects of glaciation in central and southern Alberta; Roy. Soc. Can., Trans., Vol. 35, Sec. 4.

Salisbury, R.D. (1900): The local origin of glacial drift; Jour. Geol., Vol. 8.

Solomon, J.D. (1932): The glacial succession on the Norfolk coast; Proc. Geol. Assoc., XLIII, 1932.

Stelck, C.R. (1951): Oral communication.

Taylor, D.A. (1934): Thesis, M.Sc. 1934 (Unpublished), Library, University of Alberta; Edmonton, Alberta

Trask, P.D. (1932): Origin and environment of source sediments of petroleum; Gulf Publishing Co., Huston, Texas.

Twenhofel, W.H. and Tyler, S.A. (1941): Methods of study of sediments; McGraw Hill Co., New York.

Tyrrell, J.B. (1886): Report on a part of northern Alberta and portions of adjacent districts Assiniboia and Saskatchewan; Geol. Surv., Canada, Ann. Rept. Vol. 2, Pt. E.

Udden, J.A. (1914): Mechanical composition of clastic sediments; Bull., Geol. Soc. Am., Vol. 25.

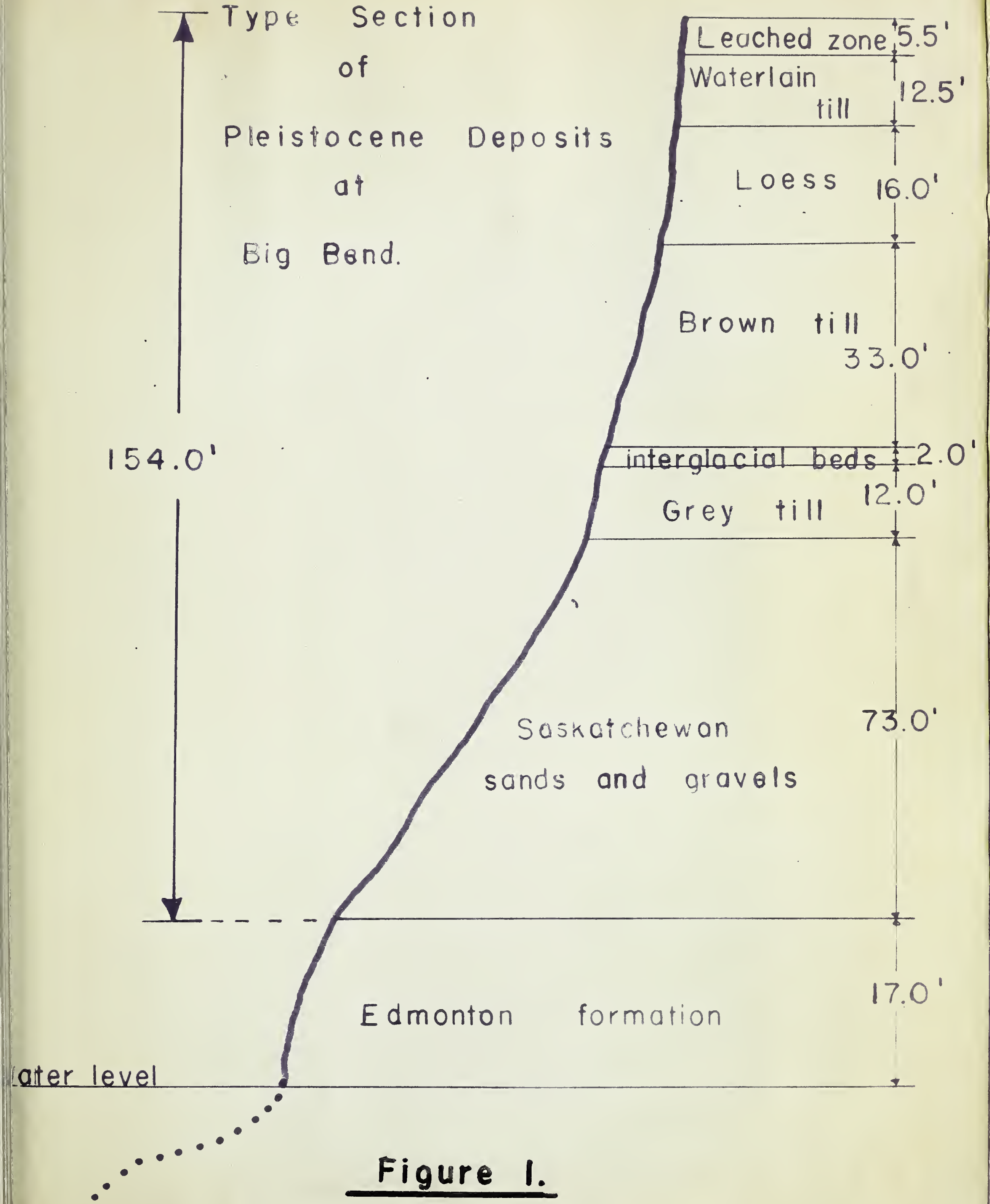
Wadell, H. (1932): Volume, shape and roundness of rock particles; Jour. Geol., Vol. 40, No. 5.

----- (1933): Sphericity and roundness of rock particles; Jour. Geol., Vol. 41, No. 3.

Wallace, R.C. and McCartney, G.C. (1928): Heavy minerals in sand horizons in Manitoba and Eastern Saskatchewan; Roy. Soc. Can., Trans., Vol. 22, Sec. 4.

Warren, P.S. (1937): The significance of the Viking moraine; Roy. Can. Inst., Trans., Vol. 21, Part 2.

----- (1950a): Unpublished manuscript on glaciation in the Edmonton area.



Type Section
of
Pleistocene Deposits
at
Big Bend.
154.0'
Leached zone 5.5'
Waterlain till 12.5'
Loess 16.0'
Brown till 33.0'
interglacial beds 2.0'
Grey till 12.0'
Saskatchewan sands and gravels 73.0'
Edmonton formation 17.0'
ater level

Figure 1.

FIGURE 2

Looking down the North Saskatchewan river from the "Big Bend". Brown till forms the steep columnar cliffs. Low angle slope is formed by the Saskatchewan sands.

FIGURE 3

Uppermost "Silt till" overlying sand and silt.

FIGURE 4

Silt till overlying varved clays. Note the cobble in the clay.

FIGURE 5

Silt till overlying Brown till. Note old erosional pebble line on the Brown till.

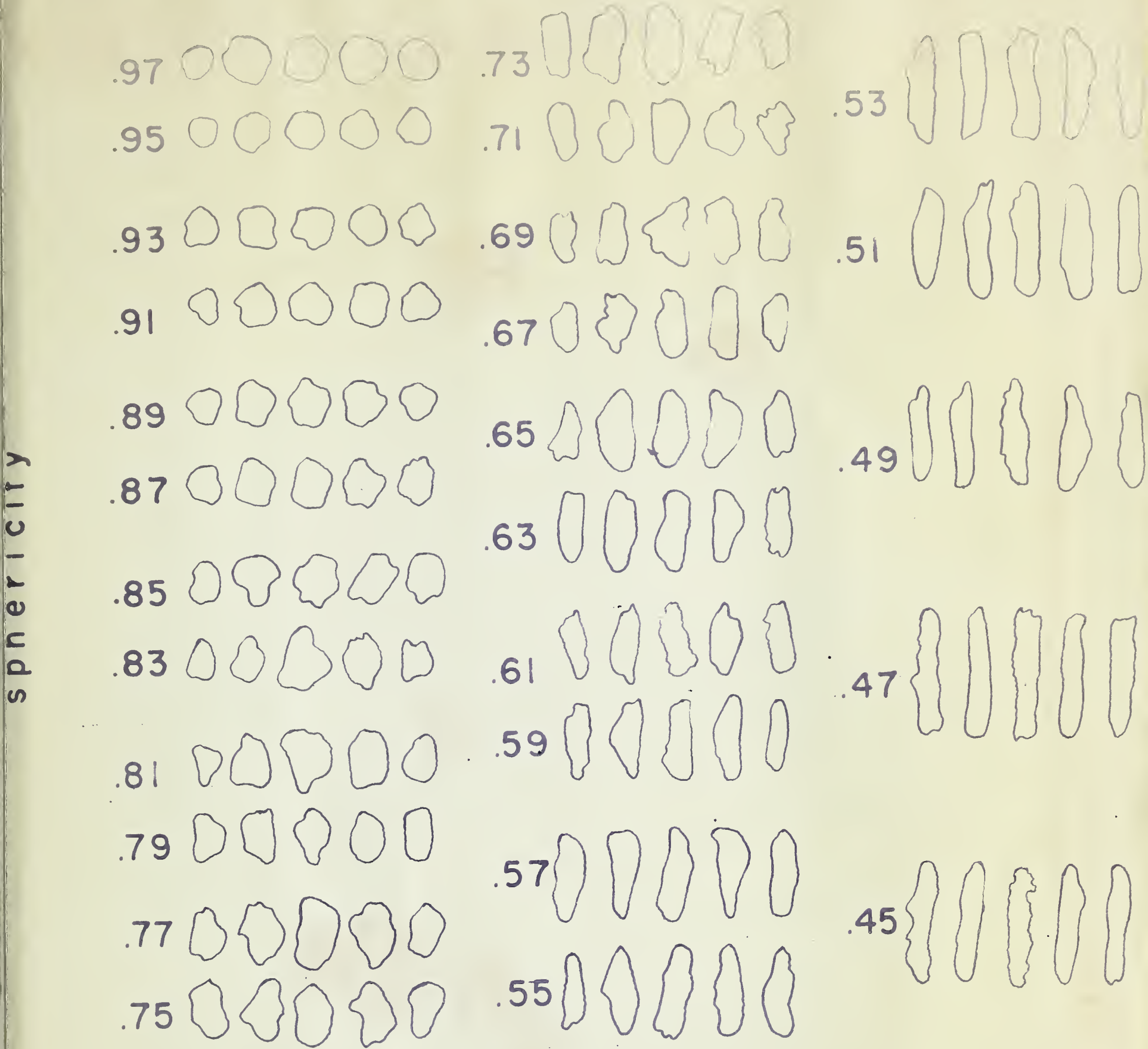


TABLE for ESTIMATING

TWO-DIMENSIONAL SPHERICITY.

FIGURE 6

reproduced from
G. Rittenhouse
in Jour. of Sed. Pet.
Vol. 13 No. 2 1943.

APPENDIX "A"

TABLES 1 to 6

Table 1

SASKATCHEWAN GRAVELS		
Specimen	Location	Stratigraphic Position
a_1	3-6-51-25 W4	below brown till
b_1	14-3-54-23 W4	below gray till
c_1	1-23-52-25 W4	below gray till
d_1	2½ miles east of Burbank, Alberta in road cut	below gray till
e_1	in Red Deer River cut bank at Labuma, Alta.	below gray till
f_1	13-31-50-26 W4	below gray till
g_1	Lothian Collieries, north shore of Lake Wabamun	below gray till
h_1	7-16-52-25 W4	below gray till

Table 2

BEDROCK, GRAY TILL, BROWN TILL, SILT TILL		
Specimen	Location	Stratigraphic Position
a_2	overall sample	Edmonton ss
b_2	overall sample	Edmonton ss
c_2	7-16-52-25 W4	in gray till
d_2	11-31-51-24 W4	gray till
e_2	16-23-52-25 W4	gray till
f_2	7- 1-52-25 W4	gray till
g_2	7-16-52-25 W4	gray till
h_2	7-16-52-25 W4	gray till
i_2	11-31-51-24 W4	brown till
j_2	7-1- 52-25 W4	brown till
k_2	16-23-52-25 W4	brown till
l_2	7-16-52-25 W4	brown till
m_2	3- 3-53-22 W4	silt till
n_2	1 mi. E. of Elk Island Park	silt till
o_2	North Cooking Lake	silt till
p_2	Tofield strip pit	silt till
q_2	Strip mine Sec1-53-20 W4	silt till

Table 3

INTERGLACIAL SANDS		
Specimen	Location	Stratigraphic Position
a_3	In Red Deer River cut bank at Labuma	on gray till interglacial
b_3	Sand pit 6 miles N of Carvel Corner	on gray till interglacial
c_3	14-3-54-23 W4	on gray till interglacial
d_3	7-16-52-25 W4	on gray till interglacial
e_3	12-24-55-25 W4	on gray till interglacial
f_3	½ mile west of Campsie P.O.	under brown till
g_3	Mearns Strip Mine	on gray till interglacial
h_3	Brockett, Alberta (Dr. Warren)	on gray till interglacial
i_3	Mearns Strip Mine	on gray till interglacial
j_3	1-5-54-21 W4	on gray till interglacial
k_3	10-26-50-19 W4	on gray till interglacial
l_3	11-30-51-24 W4	on gray till interglacial
m_3	14-36-56-26 W4	on gray till interglacial

Table 4

SANDS UNDER SILT TILL		
Specimen	Location	Stratigraphic Position
a_4	3-27-53-25 W4	under laking
b_4	1-36-56-28 W4	under silt till
c_4	1-12-53-24 W4	under laking
d_4	12-24-53-28 W4	under laking
e_4	1-12-53-24 W4	under laking
f_4	8-36-49-2 W5	under silt till
g_4	16-31-55-22 W4	under laking
h_4	5-11-52-25 W4	under silt till
i_4	1-22-56-23 W4	under silt till
j_4	12-22-52-26 W4	under silt till
k_4	50 St. - 112 Ave. Edmonton, Alberta	under silt till

Table 5

SANDS UNDER SILT TILL		
Specimen	Location	Stratigraphic Position
a_5	112 Ave. - 56 St. Edmonton	under laking
b_5	112 Ave. - 50 St.	under silt till
c_5	2-2-50-26 W4	under silt till
d_5	2-3-51-25 W4	under laking
e_5	Peace Hills at Wetaskiwin	uncovered sand
f_5	10-13-50-28 W4	under silt till
g_5	8-6-57-21 W4	uncovered sand
h_5	Valley west of Burbank	uncovered sand
i_5	Sand Hills N.E. of Whitecourt	uncovered sand
j_5	1-25-55-24 W4	under silt till
k_5	12-17-54-27 W4	under silt till
l_5	Road cut at Nevis, Alberta	under silt till
m_5	1-22-55-27 W4	under silt till
n_5	Above city gravel pit west of University of Alberta	under silt till

Table 6

MISCELLANEOUS		
Specimen	Location	Stratigraphic Position
a_6	6-12-52-25 W4	under laking
b_6	1-25-55-24 W4	under silt till
c_6	Pigeon Lake (Ma-Me-O Beach)	beach sand
d_6	5-24-51-27 W4	under silt
e_6	13-21-55-22 W4	under silt
f_6	1-18-54-27 W4	under silt
g_6	56 St. - 113 Ave. Edmonton	sand from silt till

APPENDIX "B"

Tables 1 to 6.

TABLE 1

SASKATCHEWAN SANDS
(all samples 500 grams unless otherwise stated)

Weight percent

	a_1	b_1	c_1	d_1	e_1	f_1	g_1	h_1
Mesh # 28	5.72	.24	2.54	1.34	1.76	0.88	1.36	43.32
35	10.96	2.90	18.70	5.44	10.74	2.16	14.38	17.88
48	35.08	18.86	26.42	69.86	64.08	60.26	53.34	12.64
65	29.10	39.94	28.06	12.58	13.34	20.62	22.46	14.32
100	10.52	19.64	13.64	4.98	3.96	8.22	3.82	8.36
150	4.92	8.88	5.56	2.48	2.80	3.04	1.16	2.76
200	1.90	4.82	2.82	2.14	1.92	3.36	1.40	0.64
bottoms	1.0	3.92	1.58	0.82	1.10	1.12	1.40	0.24

Cumulative percent

	a_1	b_1	c_1	d_1	e_1	f_1	g_1	h_1
Mesh # 28	5.72	0.24	2.54	1.34	1.76	0.88	1.36	43.32
35	16.68	3.14	21.24	6.78	12.50	3.04	15.74	61.20
48	51.76	22.00	47.66	76.64	76.58	63.30	69.08	73.84
65	80.86	61.94	75.72	89.22	89.92	83.92	91.54	88.16
100	91.38	81.58	89.36	94.20	93.88	92.14	95.36	96.52
150	96.30	90.46	94.92	96.68	96.68	95.18	96.52	99.28
200	98.20	95.28	97.74	98.82	98.60	98.44	97.92	99.92
bottoms	99.20	99.20	99.32	99.64	99.70	99.56	99.32	100.16

TABLE 2

BEDROCK, GRAY, BROWN AND SILT TILL
(all samples 300 grams unless otherwise stated)

	a_2	b_2	c_2	d_2	e_2	f_2	g_2	h_2	i_2	j_2	k_2	l_2	m_2	n_2	o_2	p_2	q_2
Weight percent																	
Mesh # 28	.16	.18	2.06	3.43	4.0	2.1	3.1	0.77	4.53	4.9	6.2	6.03	2.77	4.43	5.10	5.54	5.30
35	.72	.92	1.86	2.13	2.83	2.1	0.7	0.54	3.17	2.8	4.6	3.33	2.37	3.77	3.16	1.06	3.20
48	3.18	4.46	2.90	3.73	4.37	4.13	1.43	1.17	5.13	4.7	5.37	4.87	3.74	6.26	4.13	4.37	4.83
65	25.0	27.2	19.94	7.1	6.43	6.83	4.2	3.76	8.43	8.73	7.83	7.53	4.67	5.17	5.90	5.67	5.76
100	20.9	21.66	55.32	7.07	6.77	6.7	7.47	8.3	9.13	9.23	9.7	8.37	5.94	5.10	6.65	6.46	7.33
150	8.6	7.70	7.76	5.07	5.0	4.1	6.87	8.9	4.9	6.67	5.73	6.31	5.13	5.50	6.30	5.70	5.77
200	4.69	3.84	4.54	4.37	4.0	2.63	8.43	8.1	4.23	4.87	4.77	5.25	4.44	5.96	6.35	5.20	5.50
bottoms	36.6	34.04	5.04	67.1	66.6	71.4	67.8	68.6	60.47	58.1	55.8	58.3	71.2	63.80	63.40	66.10	63.10
Cumulative percent																	
Mesh # 28	.16	.18	2.06	3.43	4.0	2.1	3.1	0.77	4.53	4.7	6.2	6.03	2.77	4.43	5.10	5.54	5.30
35	.88	1.10	3.92	5.46	6.83	4.2	3.8	1.31	7.70	7.7	10.8	9.36	5.14	8.20	8.26	6.60	8.50
48	4.06	5.56	6.82	9.19	11.20	8.33	5.23	2.48	12.83	12.40	16.17	14.23	8.88	14.46	12.39	10.97	13.33
65	29.06	32.76	26.76	16.29	17.63	15.16	9.43	6.24	21.26	21.13	24.00	21.75	13.55	19.63	18.29	16.64	19.09
100	49.96	54.32	82.08	23.36	24.40	21.86	16.90	14.54	30.39	30.36	33.7	30.12	19.49	24.73	24.94	23.10	26.42
150	58.56	62.02	89.84	28.43	29.90	25.96	23.77	23.44	35.29	37.03	39.43	36.43	24.62	30.23	31.24	28.80	32.19
200	63.25	65.86	94.38	32.80	33.40	28.59	32.20	31.54	39.52	41.90	45.20	41.68	29.06	36.19	37.59	34.00	37.69
bottoms	99.85	99.90	99.42	99.9	100.00	99.99	100.00	100.14	99.99	100.00	100.00	99.98	100.26	99.99	100.99	100.10	100.79
	(320 gm.)	(500 gm.)	(500 gm.)					(520 gm.)									

TABLE 3

INTERGLACIAL SANDS
(all samples 500 grams unless otherwise stated)

	a_3	b_3	c_3	d_3	e_3	f_3	g_3	h_3	i_3	j_3	k_3	l_3	m_3
Weight percent													
Mesh # 28	1.26	0.18	0.62	2.72	10.64	10.14	-	0.14	5.74	2.98	0.15	11.54	0.44
35	1.18	3.58	4.30	4.56	16.58	14.12	2.24	0.64	20.98	6.92	1.05	18.94	2.82
48	23.78	82.24	63.42	78.36	49.36	55.56	69.56	7.66	43.46	25.22	12.85	62.08	42.06
65	51.32	11.06	19.96	6.16	11.96	11.28	12.84	14.62	16.32	46.30	63.95	2.58	40.84
100	11.62	2.12	6.64	3.96	5.32	4.0	6.96	13.18	6.36	8.38	12.45	1.18	5.66
150	4.16	0.24	2.42	1.28	2.42	1.82	3.84	10.24	3.26	1.78	4.6	0.78	3.34
200	2.98	0.14	0.96	1.96	1.54	1.64	3.48	32.28	2.06	2.42	2.2	0.84	2.16
bottoms	3.04	0.14	0.94	0.84	1.46	0.98	0.92	21.62	1.44	5.48	2.05	1.56	2.28
Cumulative percent													
Mesh # 28	1.26	0.18	0.62	2.72	10.64	10.14	-	0.14	5.74	2.98	0.15	11.54	0.44
35	2.44	3.76	4.92	7.28	27.22	24.16	2.24	0.78	26.72	9.90	1.2	30.48	3.26
48	26.22	86.00	68.34	85.64	76.58	79.82	71.80	8.44	70.18	35.12	14.05	92.56	45.32
65	77.54	97.06	88.30	91.80	88.54	91.10	84.64	23.06	86.50	81.42	78.00	95.14	86.16
100	89.16	99.18	94.94	95.76	93.86	95.10	91.60	36.24	92.86	89.80	90.45	96.32	91.82
150	93.32	99.42	97.36	97.04	96.26	96.92	95.44	46.48	96.12	91.58	95.05	97.10	95.16
200	96.30	99.56	98.32	99.00	97.80	98.56	98.92	78.76	98.18	94.00	97.25	97.94	97.32
bottoms	99.34	99.70	99.26	99.84	99.26	99.54	99.84	100.38	99.62	99.48	99.50	99.50	99.60
				(250 gm.)			(250 gm.)				(200 gm.)		

TABLE 4

SANDS UNDER SILT TILL
(all samples 500 grams unless otherwise stated)

		a4	b4	c4	d4	e4	f4	g4	h4	i4	j4	k4
Weight percent												
Mesh #	28	0.82	0.66	0.1	0.88	10.08	2.06	0.72	0.32	0.96	0.16	1.97
	35	0.7	2.28	1.70	1.72	11.88	6.58	2.44	3.22	0.66	0.3	3.7
	48	40.25	43.36	44.98	44.98	42.18	42.44	43.98	49.60	46.50	40.82	40.07
	65	43.16	44.25	37.24	35.06	26.46	32.94	36.00	29.24	32.32	25.54	25.58
	100	6.66	6.12	8.38	6.42	2.58	6.14	5.84	9.94	10.16	11.44	6.45
	150	4.28	1.98	4.14	4.00	1.50	3.44	2.92	4.08	3.24	8.12	2.52
	200	2.34	0.58	1.96	3.58	2.46	3.34	4.58	1.88	2.84	8.92	7.27
	bottoms	1.56	0.48	1.16	3.14	2.38	2.88	3.32	1.26	3.10	4.64	11.57
Cumulative percent												
Mesh #	28	0.82	0.66	0.1	0.88	10.08	2.06	0.72	0.32	0.96	0.16	1.97
	35	1.52	2.94	1.80	2.60	21.96	8.64	3.16	3.54	1.62	0.46	5.67
	48	41.77	46.30	46.78	47.58	64.14	51.08	47.14	53.14	48.12	41.28	45.74
	65	84.93	90.55	84.02	82.64	90.60	84.02	83.14	82.38	80.44	66.82	71.32
	100	91.59	96.67	92.40	89.06	93.18	90.16	88.98	92.32	90.60	78.26	77.77
	150	95.87	98.65	96.54	93.06	94.68	93.60	91.90	96.40	93.84	86.38	80.29
	200	98.21	99.23	98.50	96.64	97.14	96.94	96.48	98.28	96.68	95.30	87.56
	bottoms	99.77	99.71	99.66	99.78	99.52	99.82	99.80	99.54	99.78	99.94	99.13
												(400 gms)

TABLE 5

SANDS UNDER SILT TILL
(all samples 500 grams unless otherwise stated)

Weight percent

	a_5	b_5	c_5	d_5	e_5	f_5	g_5	h_5	i_5	j_5	k_5	l_5	m_5	n_5
Mesh # 28	1.13	1.28	0.32	2.46	3.34	7.02	0.22	3.72	0.14	3.34	0.82	1.82	3.42	3.82
35	3.6	3.32	4.98	11.98	12.96	10.22	9.04	18.06	1.90	18.32	11.08	11.70	4.70	18.48
48	57.2	63.56	73.92	68.72	73.52	65.52	75.94	53.98	65.08	61.94	64.88	52.68	68.72	50.00
65	15.57	14.78	10.58	9.14	4.54	8.02	7.98	13.82	16.00	11.96	14.42	20.74	12.60	17.18
100	7.47	2.86	3.06	2.96	2.50	3.02	4.58	6.02	8.68	2.28	4.34	4.14	3.88	4.98
150	4.97	2.38	1.42	1.78	1.62	2.04	1.18	2.48	3.88	1.12	2.04	2.94	1.64	2.40
200	5.6	4.88	2.02	1.46	1.14	11.94	0.58	1.32	3.26	0.54	1.0	3.82	1.94	1.24
bottoms	4.13	7.78	3.62	1.26	0.26	1.92	0.14	0.4	1.02	0.34	0.96	1.58	2.80	1.36

Cumulative percent

	a_5	b_5	c_5	d_5	e_5	f_5	g_5	h_5	i_5	j_5	k_5	l_5	m_5	n_5
Mesh # 28	1.13	1.28	0.32	2.46	3.34	7.02	0.22	3.72	0.14	3.34	0.82	1.82	3.42	3.82
35	4.73	4.60	5.30	14.44	16.30	7.24	9.26	21.78	2.04	21.66	11.90	13.52	8.12	22.30
48	61.93	68.16	79.22	83.16	89.82	82.76	85.20	75.76	67.12	83.60	76.78	66.20	76.84	72.30
65	77.50	82.94	89.80	92.30	94.36	90.78	93.18	89.58	83.12	95.56	91.20	86.94	89.44	89.48
100	84.97	85.80	92.86	95.26	96.86	93.80	97.76	95.60	91.70	97.84	95.54	91.08	93.32	94.46
150	89.94	88.18	94.28	97.04	98.48	95.85	98.94	98.08	95.58	98.96	97.58	94.02	94.96	96.86
200	95.54	93.06	96.30	98.50	99.62	97.78	99.52	99.40	98.84	99.50	98.58	97.82	96.90	98.10
bottoms	99.69	100.84	99.92	99.76	99.88	99.70	99.66	99.80	99.86	99.84	99.54	99.40	99.70	99.46

TABLE 6

MISCELLANEOUS SANDS
(all samples 500 grams unless otherwise stated)

		a_6	b_6	c_6	d_6	e_6	f_6	g_6
Weight percent								
Mesh #	28	7.30	5.52	21.18	19.74	60.46	2.28	1.6
	35	36.62	24.76	64.84	63.82	28.56	3.80	2.3
	48	46.72	59.20	9.92	13.82	8.28	13.76	4.73
	65	6.78	7.58	2.88	1.70	1.66	41.46	6.26
	100	1.58	1.48	0.56	0.24	0.38	9.62	17.1
	150	0.42	0.58	0.12	0.08	0.08	7.68	16.26
	200	0.24	0.32	-	0.04	0.18	8.74	33.8
	bottoms	0.18	0.16	-	0.02	0.06	12.28	16.86
Cumulative percent								
Mesh #	28	7.30	5.52	21.18	19.74	60.46	2.28	1.6
	35	43.92	30.28	86.02	83.56	89.02	6.08	3.9
	48	90.64	89.48	95.95	97.38	97.30	19.84	8.63
	65	97.42	97.06	98.82	99.08	98.96	61.30	14.89
	100	99.00	98.54	99.38	99.32	99.34	70.92	31.99
	150	99.42	99.12	99.50	99.40	99.42	78.60	48.25
	200	99.66	99.44	-	99.44	99.60	87.34	82.05
	bottoms	99.84	99.60	-	99.46	99.66	99.62	98.91

APPENDIX C

Tables 1 to 6

Table 1.

Saskatchewan Sands.

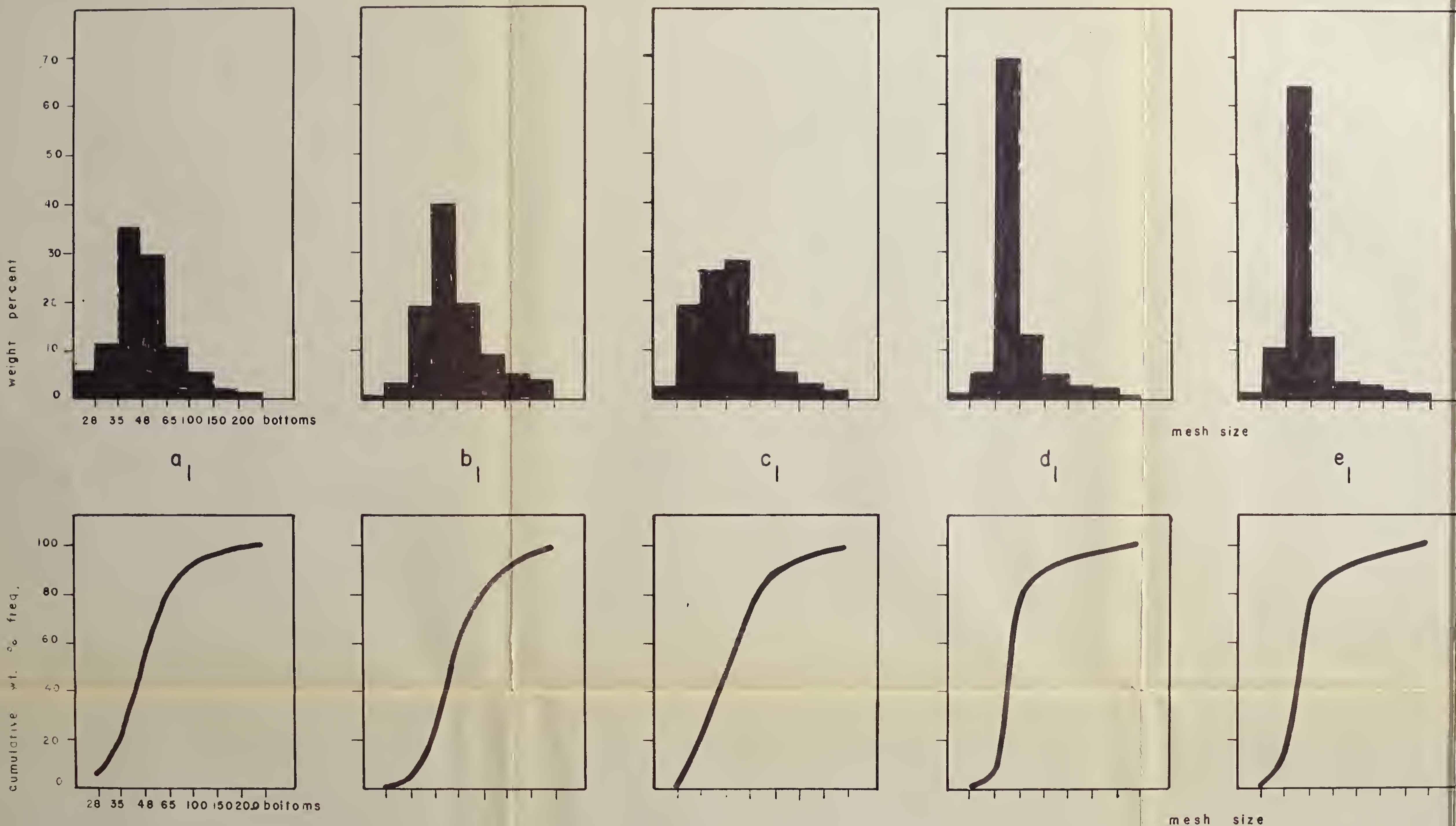
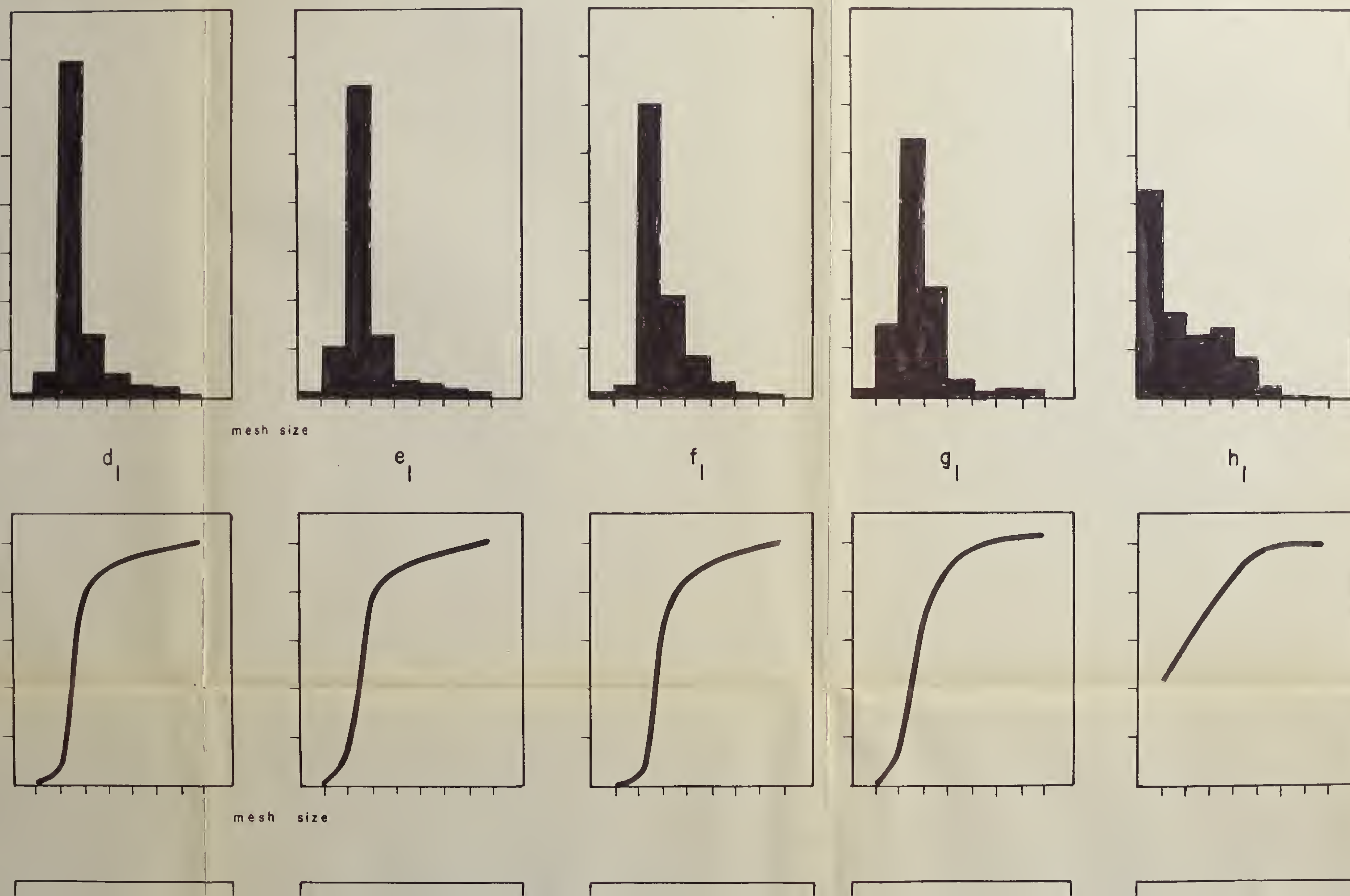
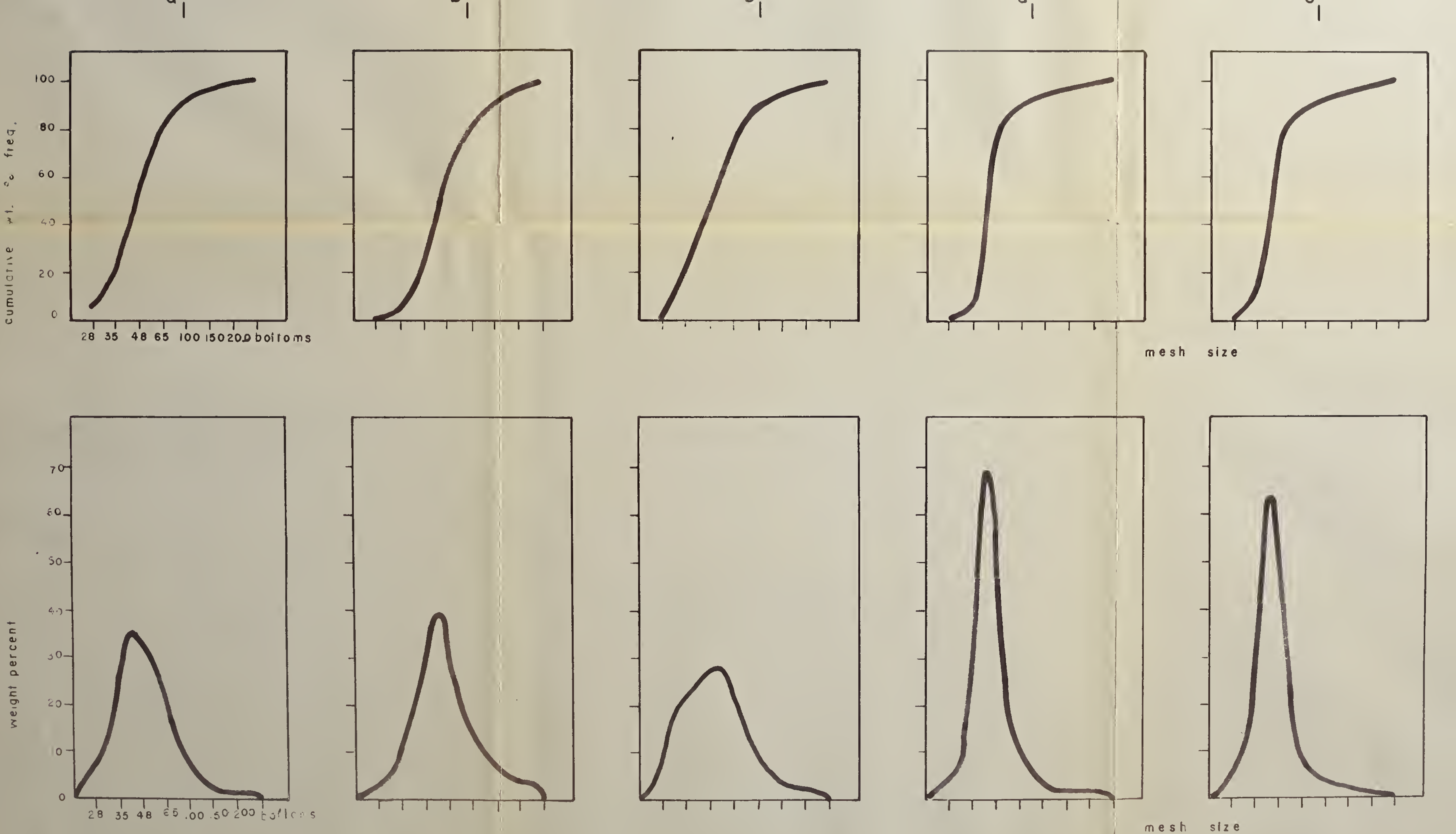
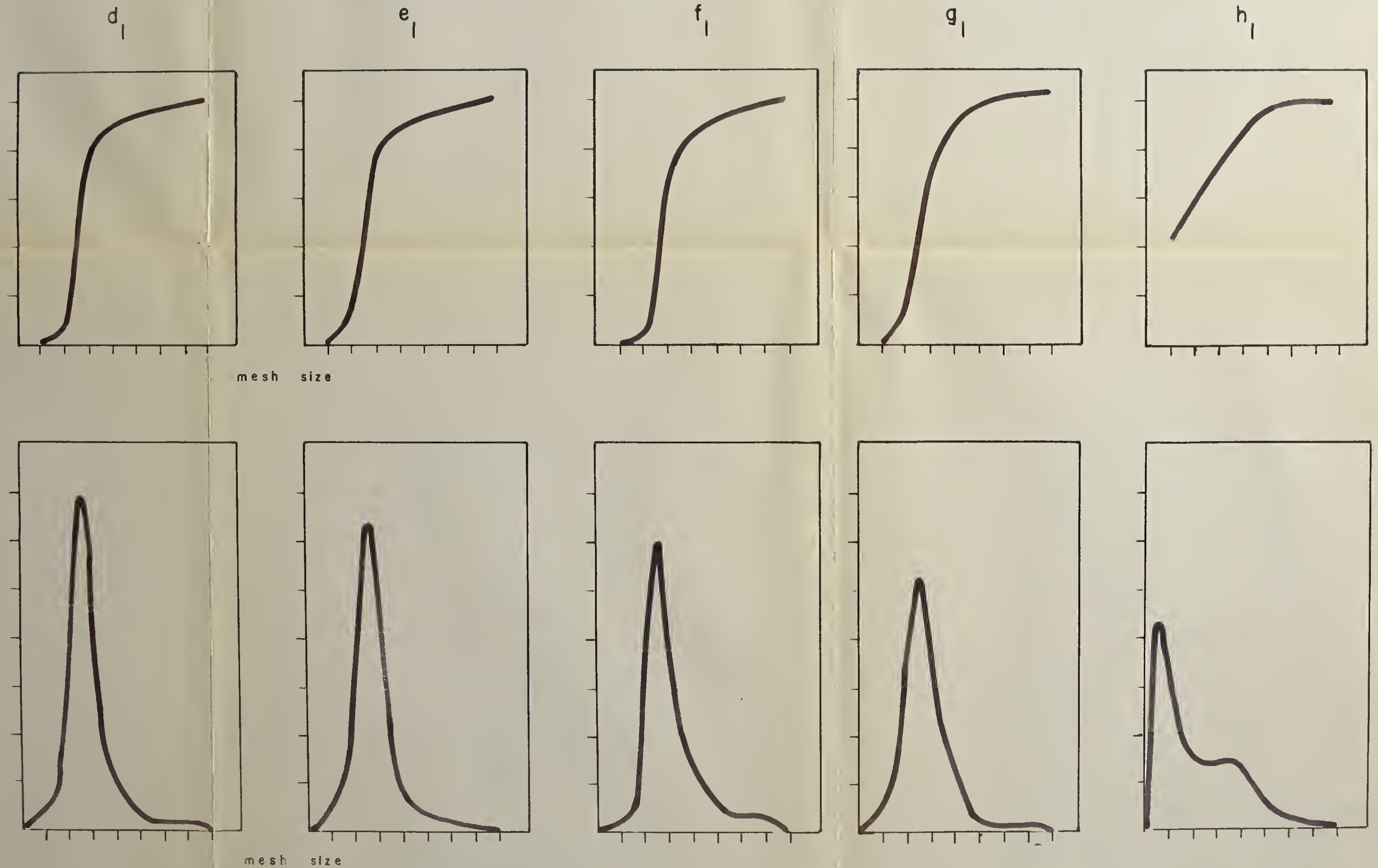


Table 1.



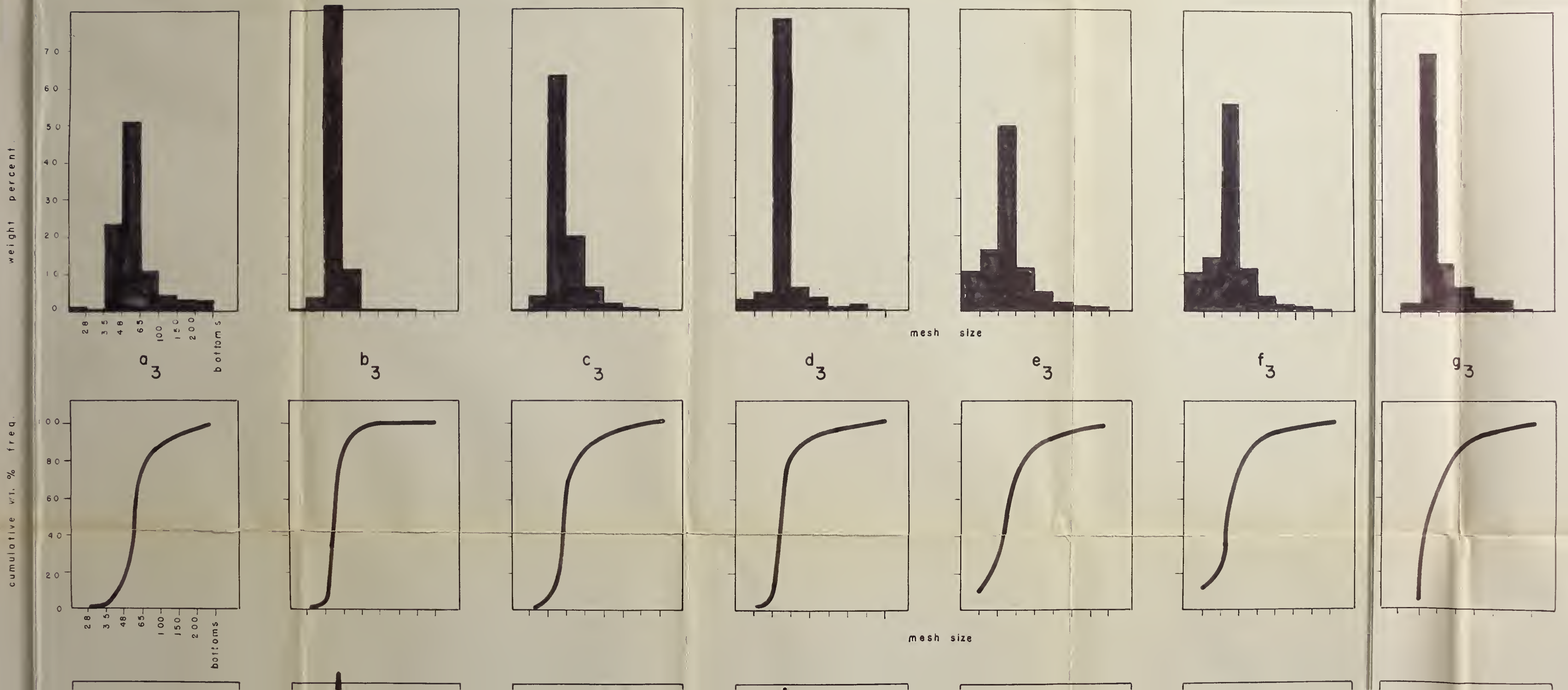

cumulative wt. % freq.
100
80
60
40
20
0
28 35 48 65 100 150 200 bottoms
mesh size
weight percent
70
60
50
40
30
20
10
0
28 35 48 65 100 150 200
mesh size

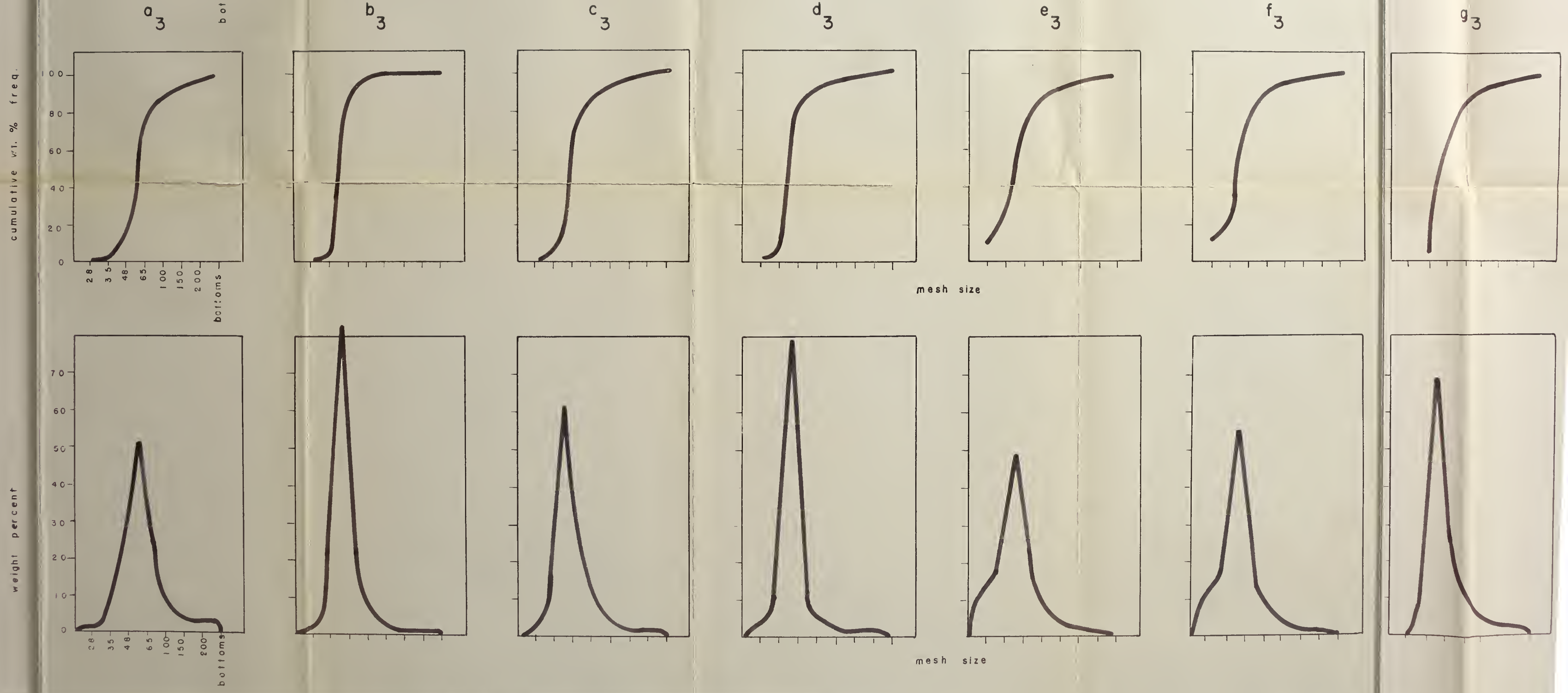


d_1
e_1
f_1
g_1
h_1
mesh size
mesh size

Table 3.

Interglacial Sands.

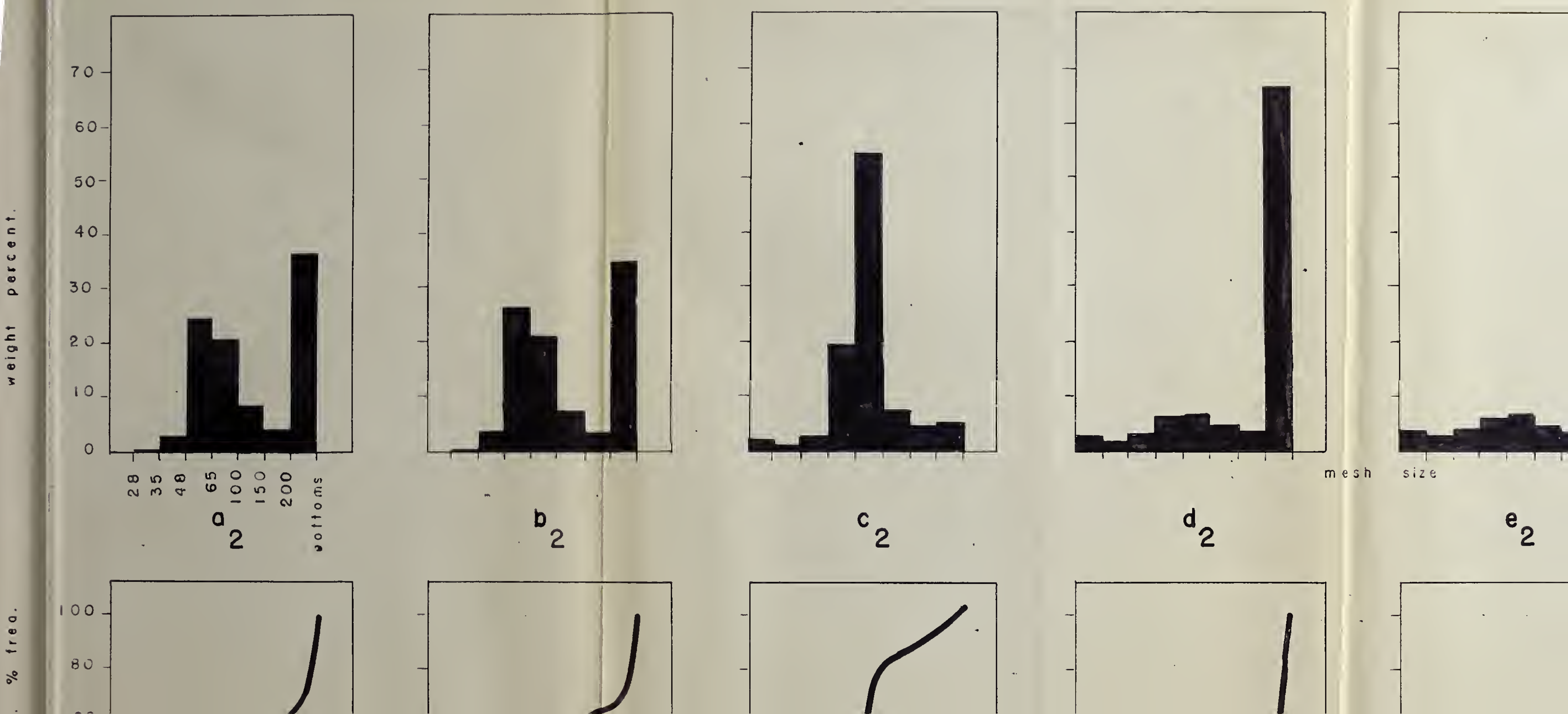




a_3
b_3
c_3
d_3
e_3
f_3
g_3
cumulative wt. % freq.
0
20
40
60
80
100
28
35
48
65
100
150
200
bottoms
mesh size
weight percent
0
10
20
30
40
50
60
70
mesh size

70
60
50
40
30
20
10
0
28
35
48
65
100
150
200
bottoms
mesh size
h3
i3
j3
k3
l3
m3
100
80
60
20
0

Bedrock, Gray Till, Brown Till, Silt Till.



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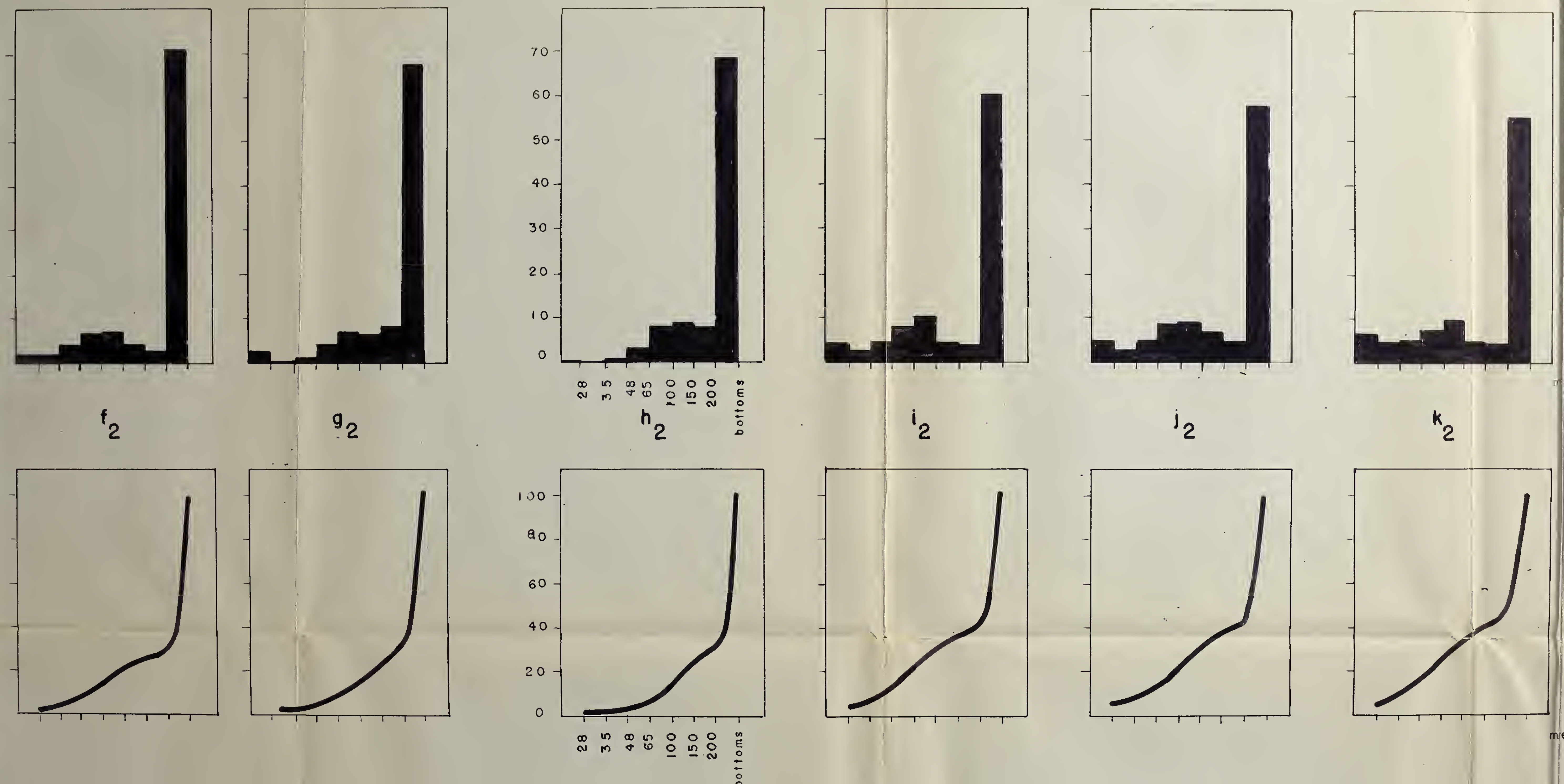

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60
50
40
30
20
10
0
28
35
48
65
100
150
200
bottoms
f2
g2
h2
i2
j2
k2
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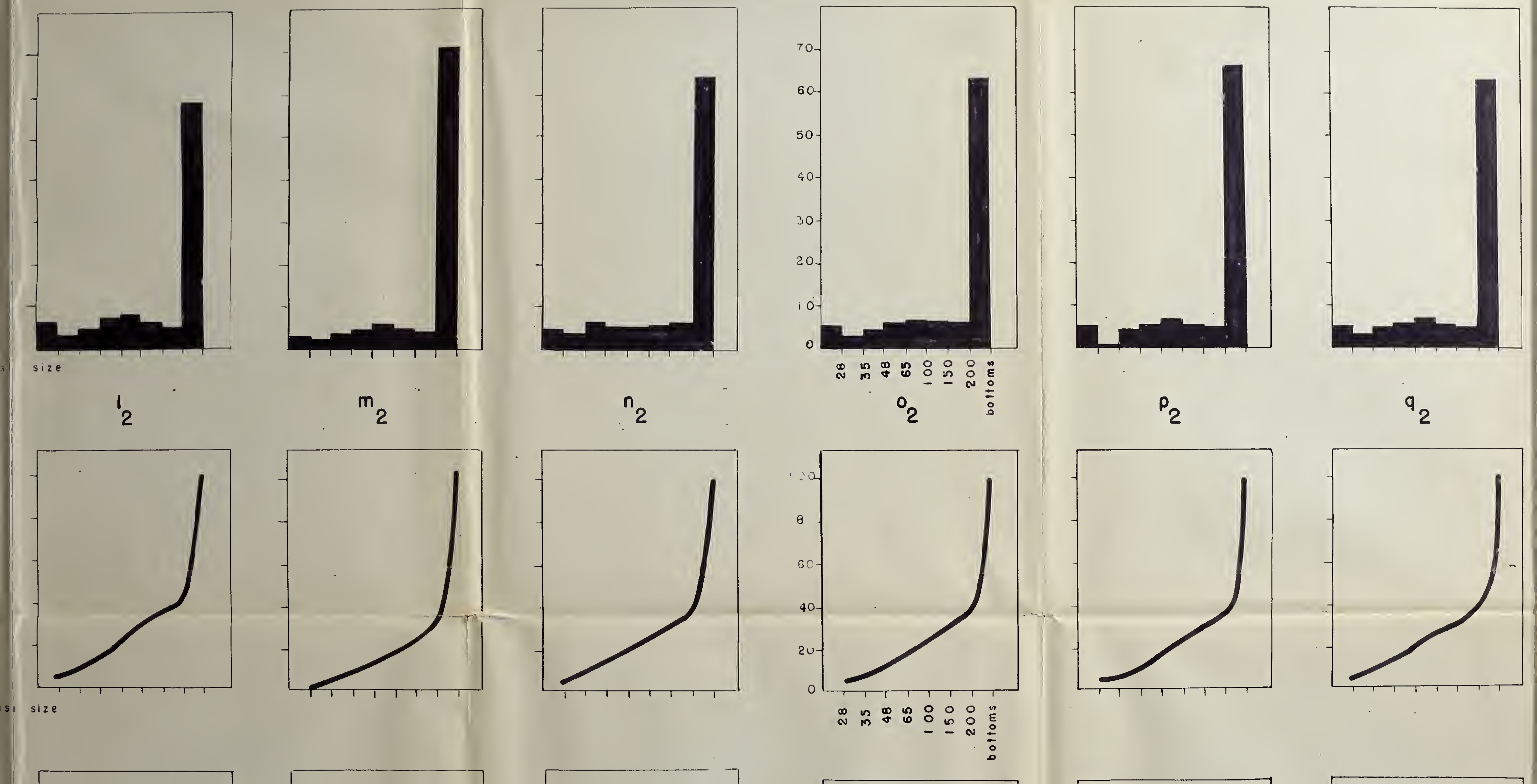
80
60
40
20
0
28
35
48
65
100
150
200
bottoms
mes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bottoms
size
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m_2
n_2
o_2
p_2
q_2
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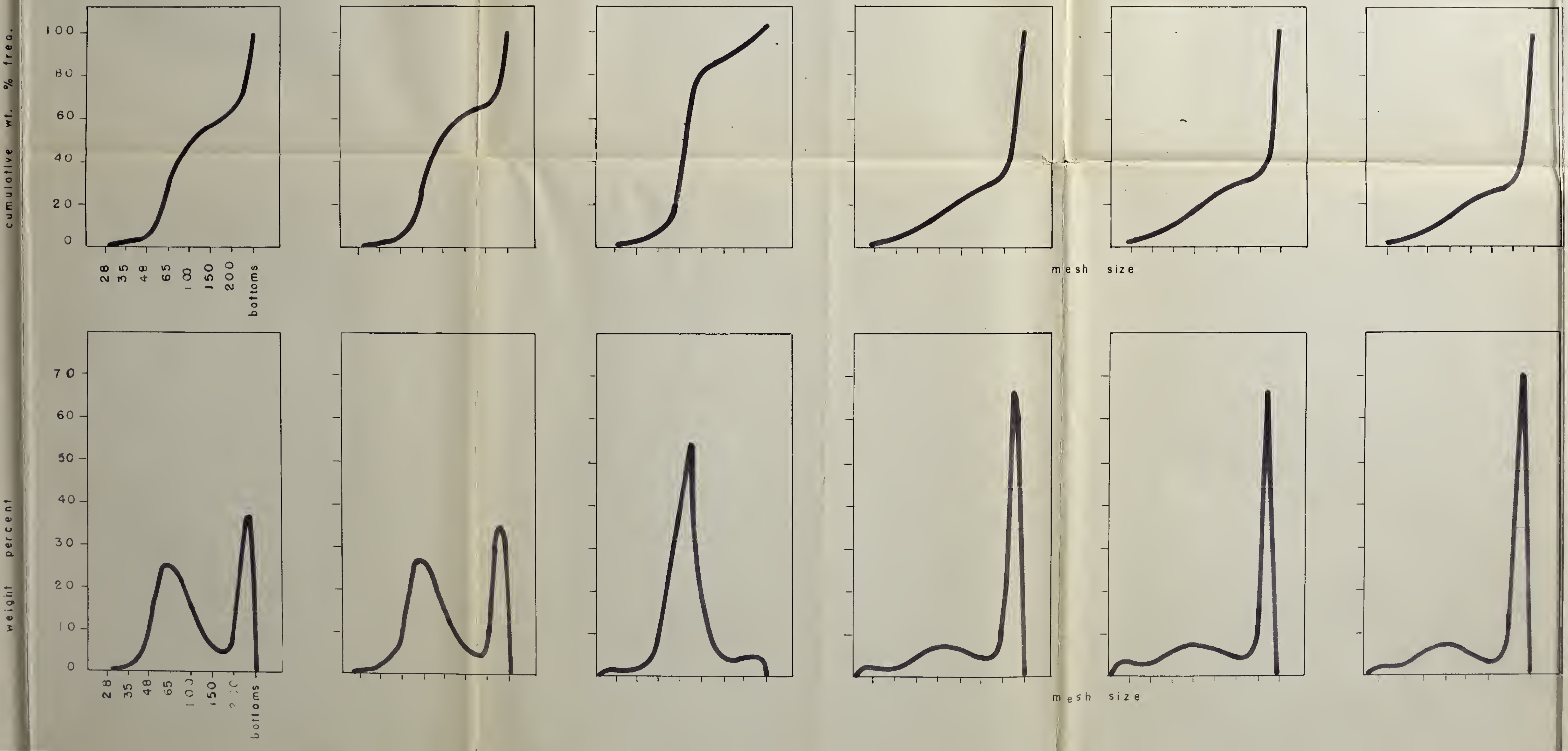
40
20
0
size



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200
bottoms
mesh size
weight percent
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40
30
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0
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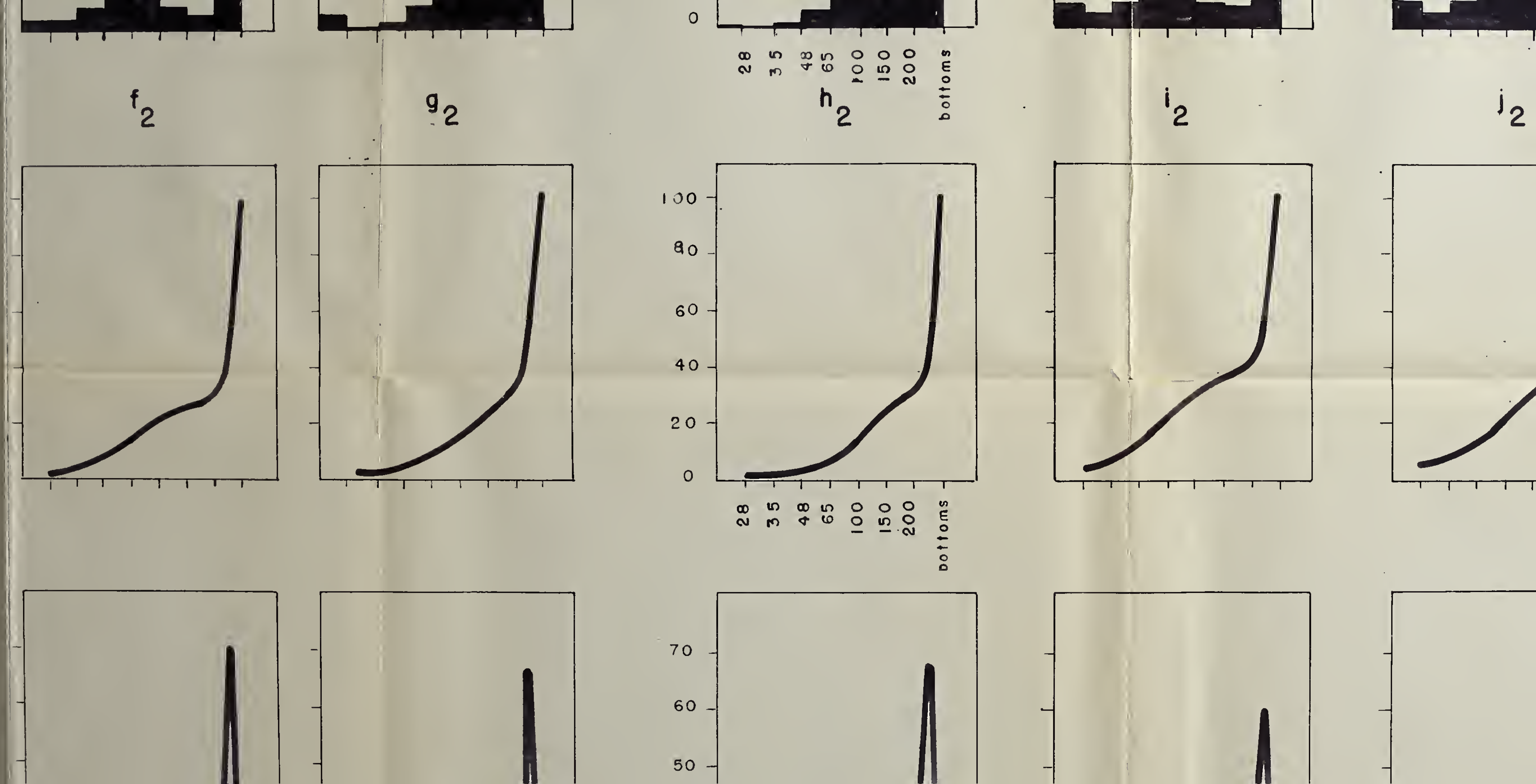
48
65
100
150
200
bottoms
mesh size



f2
g2
h2
i2
j2
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150
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bottoms
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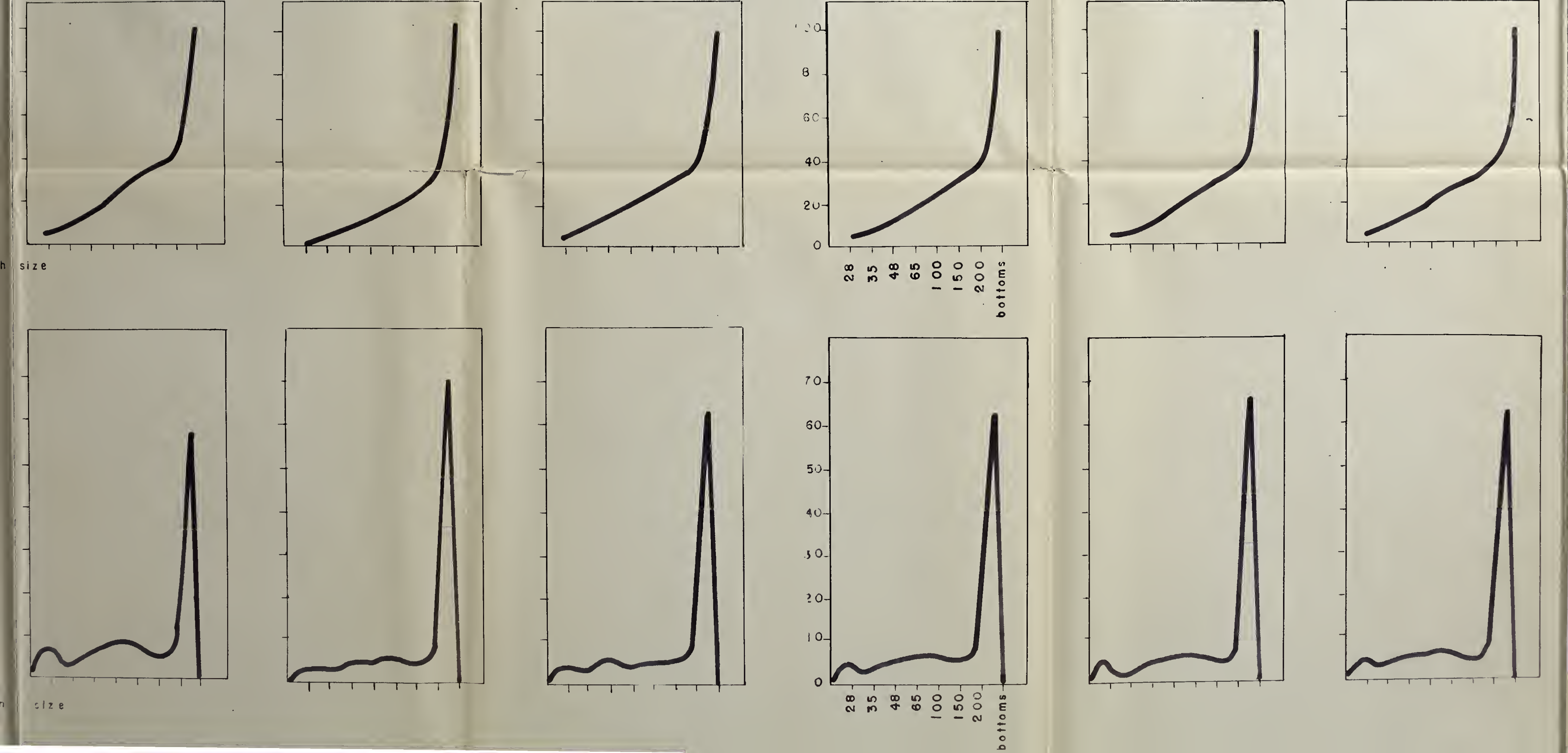

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100
150
200
bottoms
70
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0
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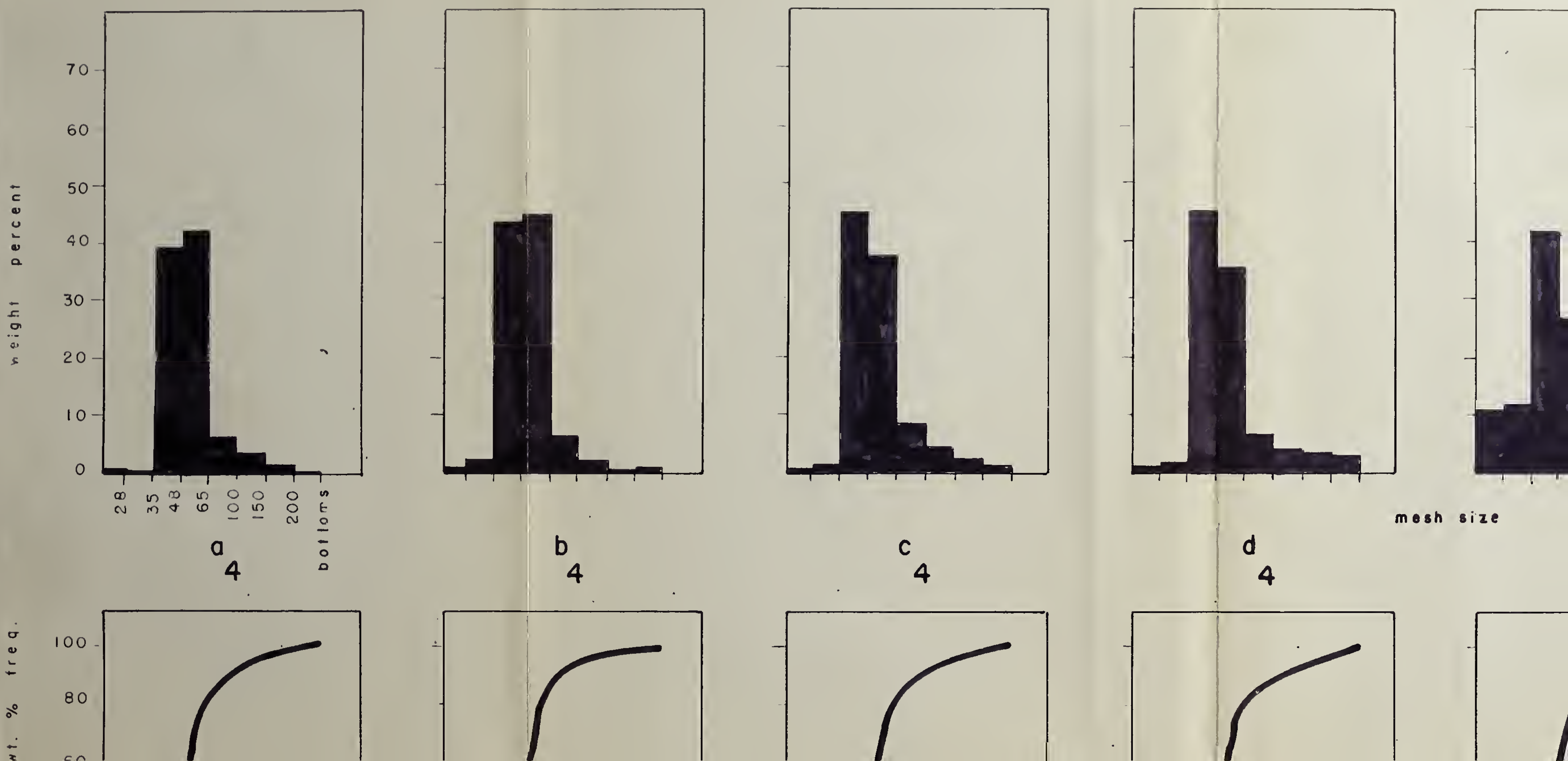
35
48
65
100
150
200
bottoms

Sands under Silt Till.



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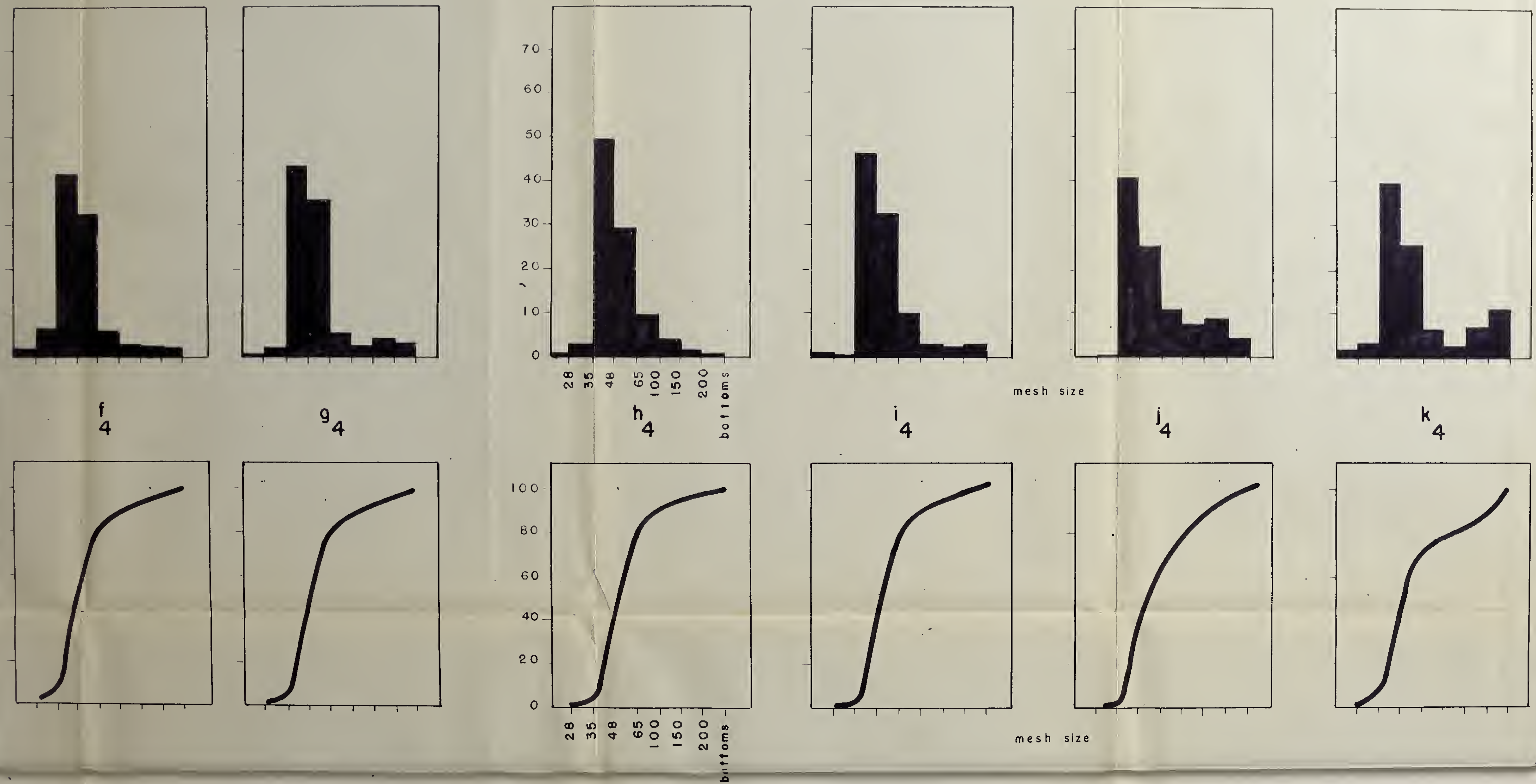
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65
100
150
200
bottoms
mesh size
f_4
g_4
h_4
i_4
j_4
k_4
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40
60
80
100
28
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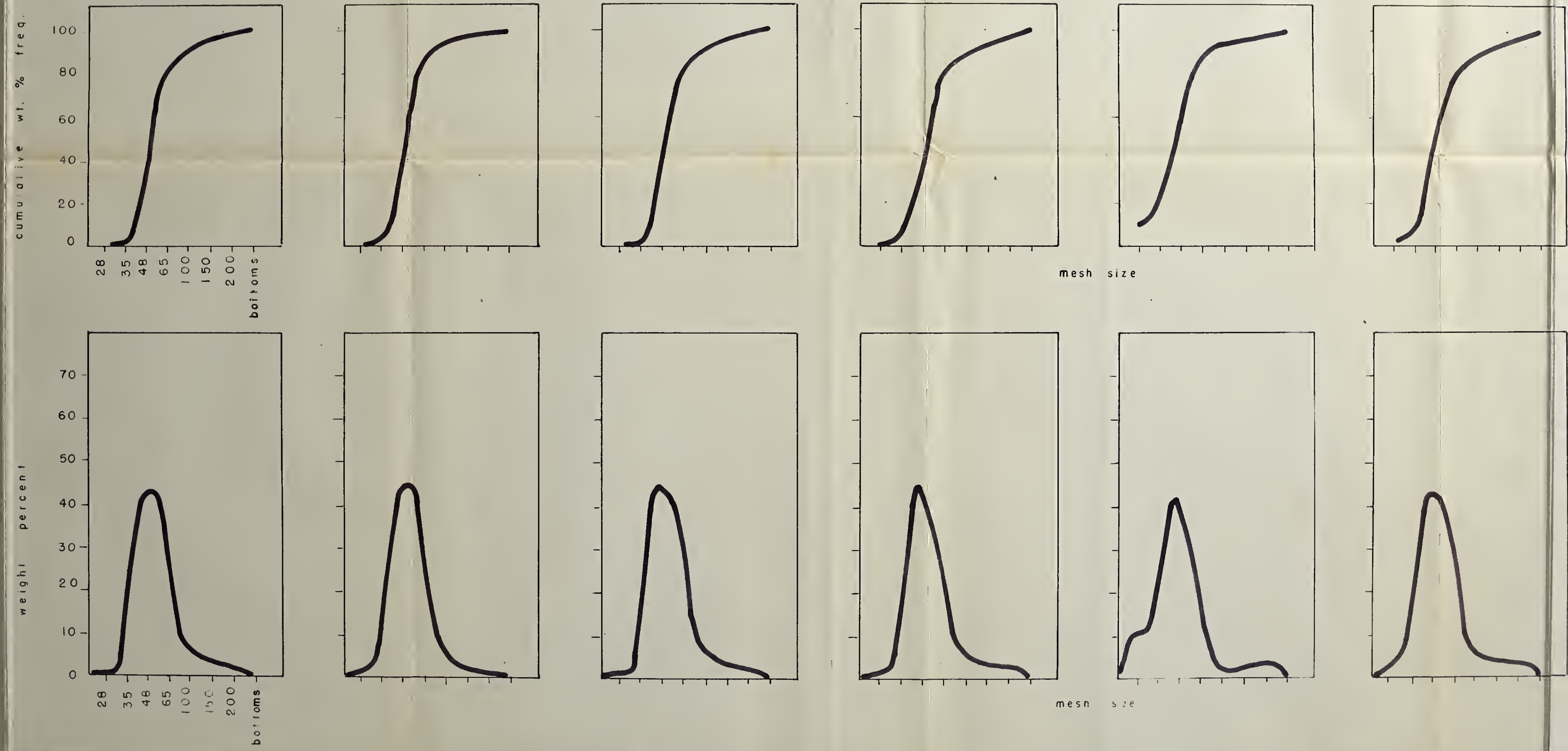
48
65
100
150
200
bottoms
mesh size



cumulative wt. % freq.
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65
100
150
200
bottoms
mesh size
weight percent
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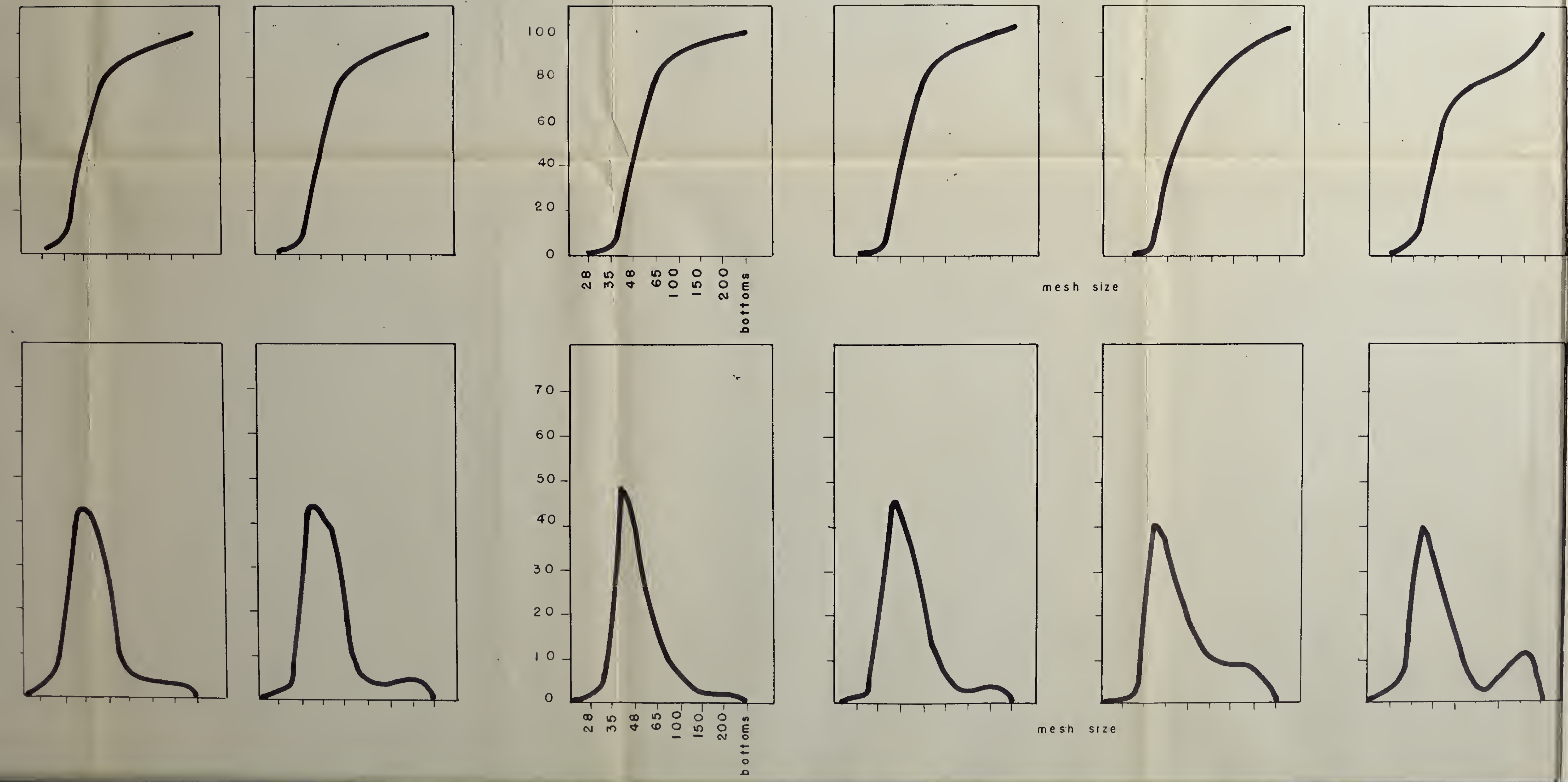
150
200
bottoms
mesh size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150
200
bottoms
mesh size
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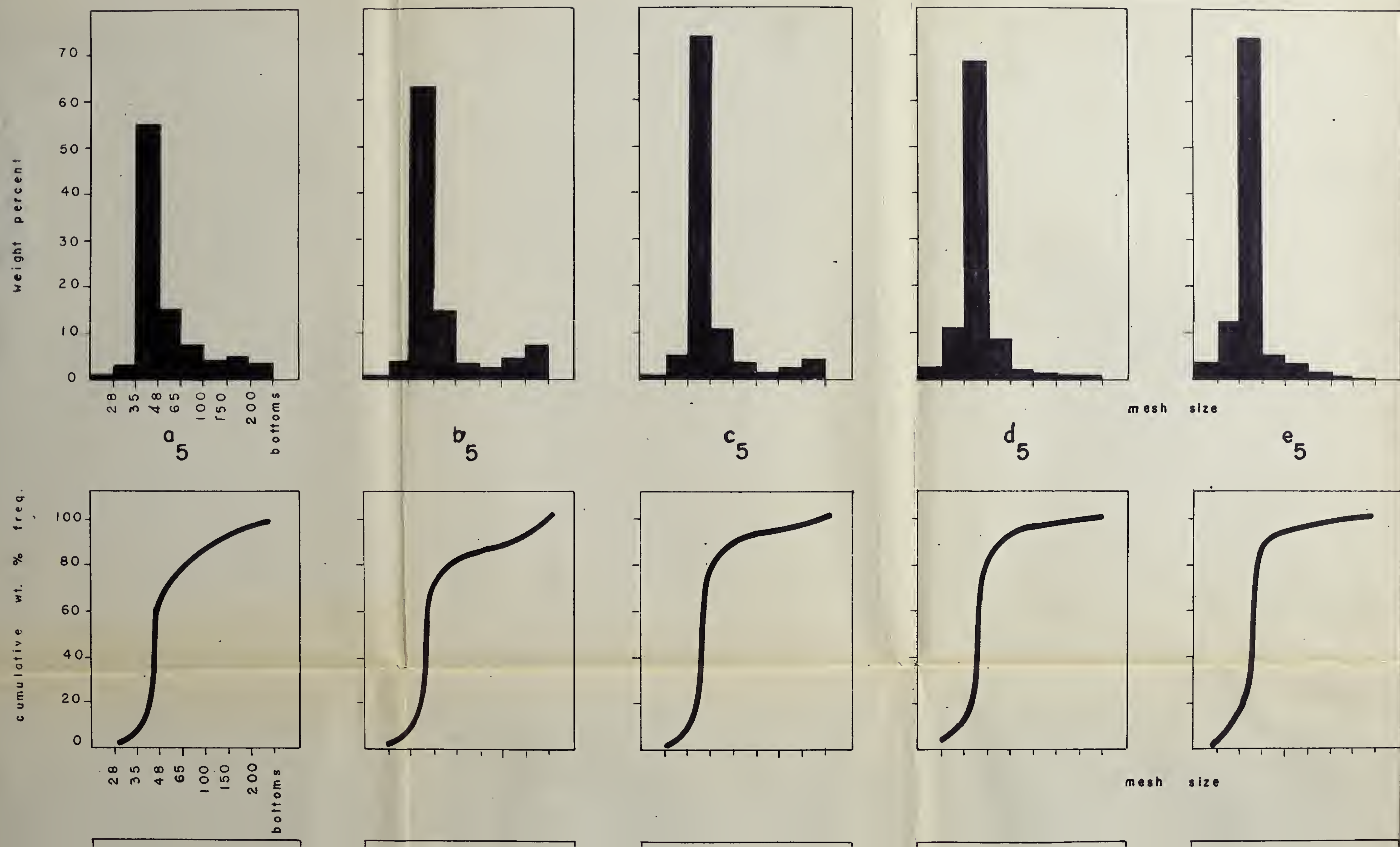
100
150
200
bottoms
mesh size

Sands under Silt Till.



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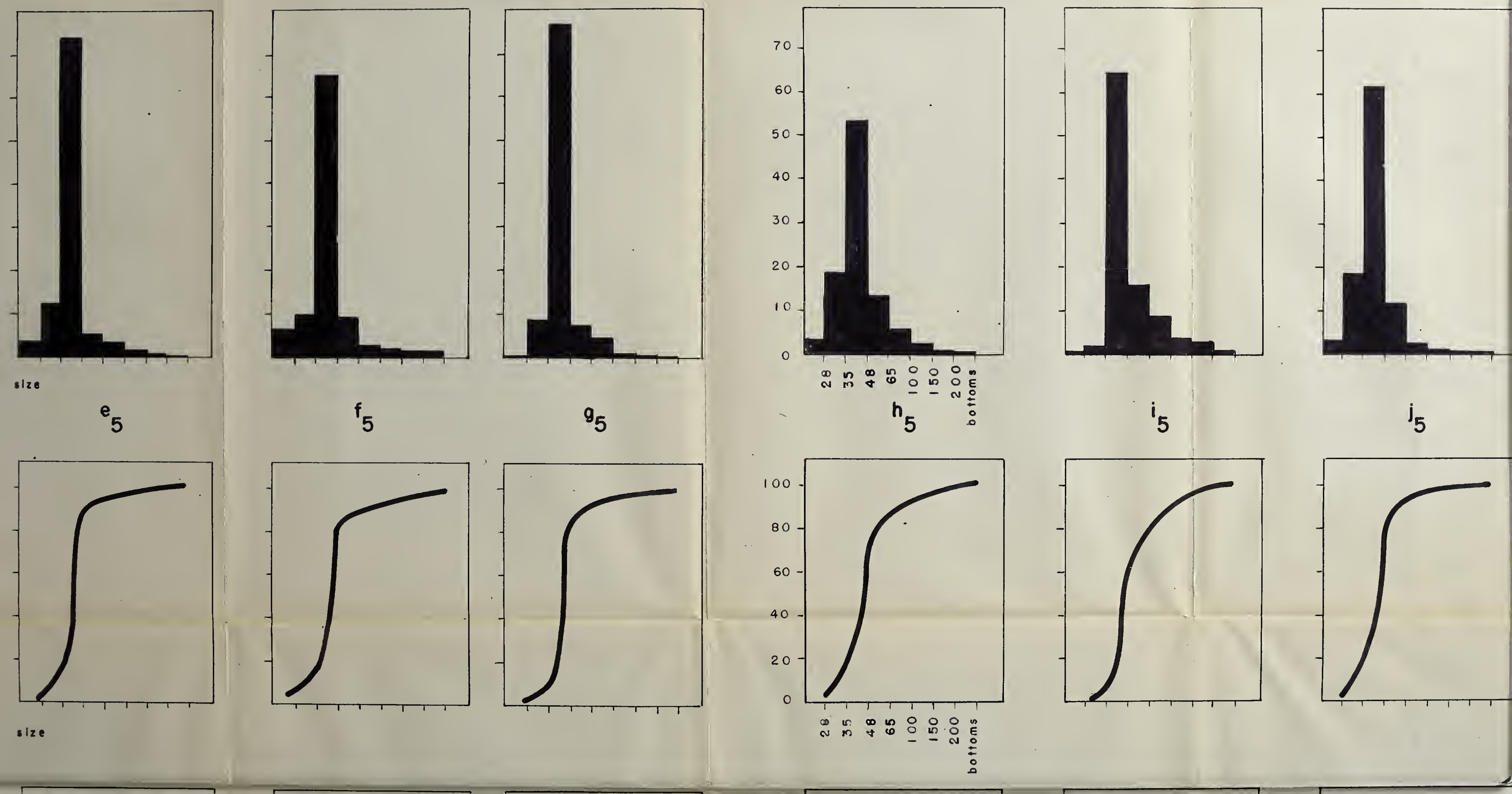
70
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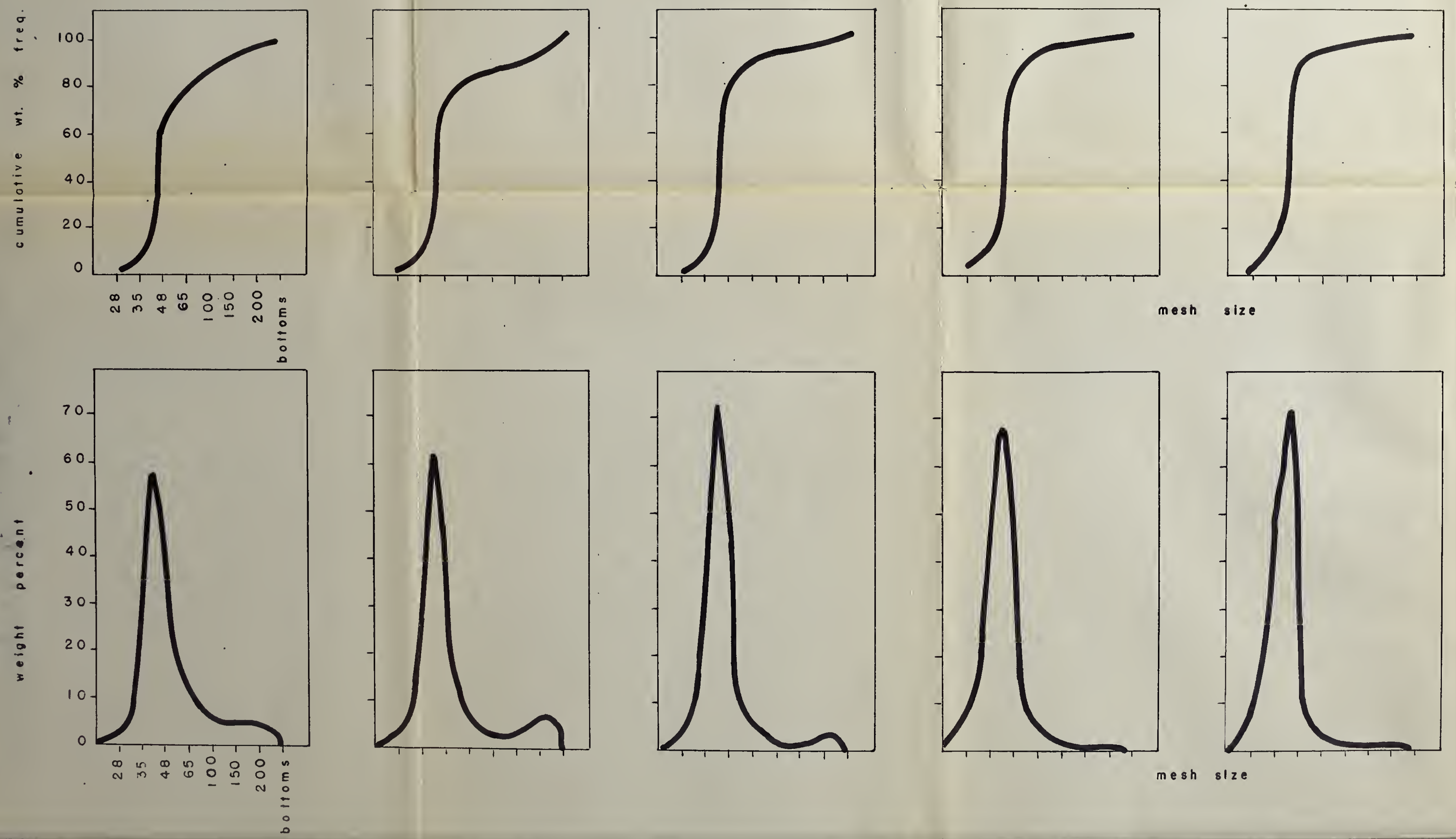
50
40
30
20
10
0
28 35 48 65 100 150 200 bottoms
size
e_5
f_5
g_5
h_5
i_5
j_5
100
80
60
40
20
0
28 35 48 65 100 150 200 bottoms
size



cumulative wt. % freq.
100
80
60
40
20
0
28
35
48
65
100
150
200
bottoms
mesh size
weight percent
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50
40
30
20
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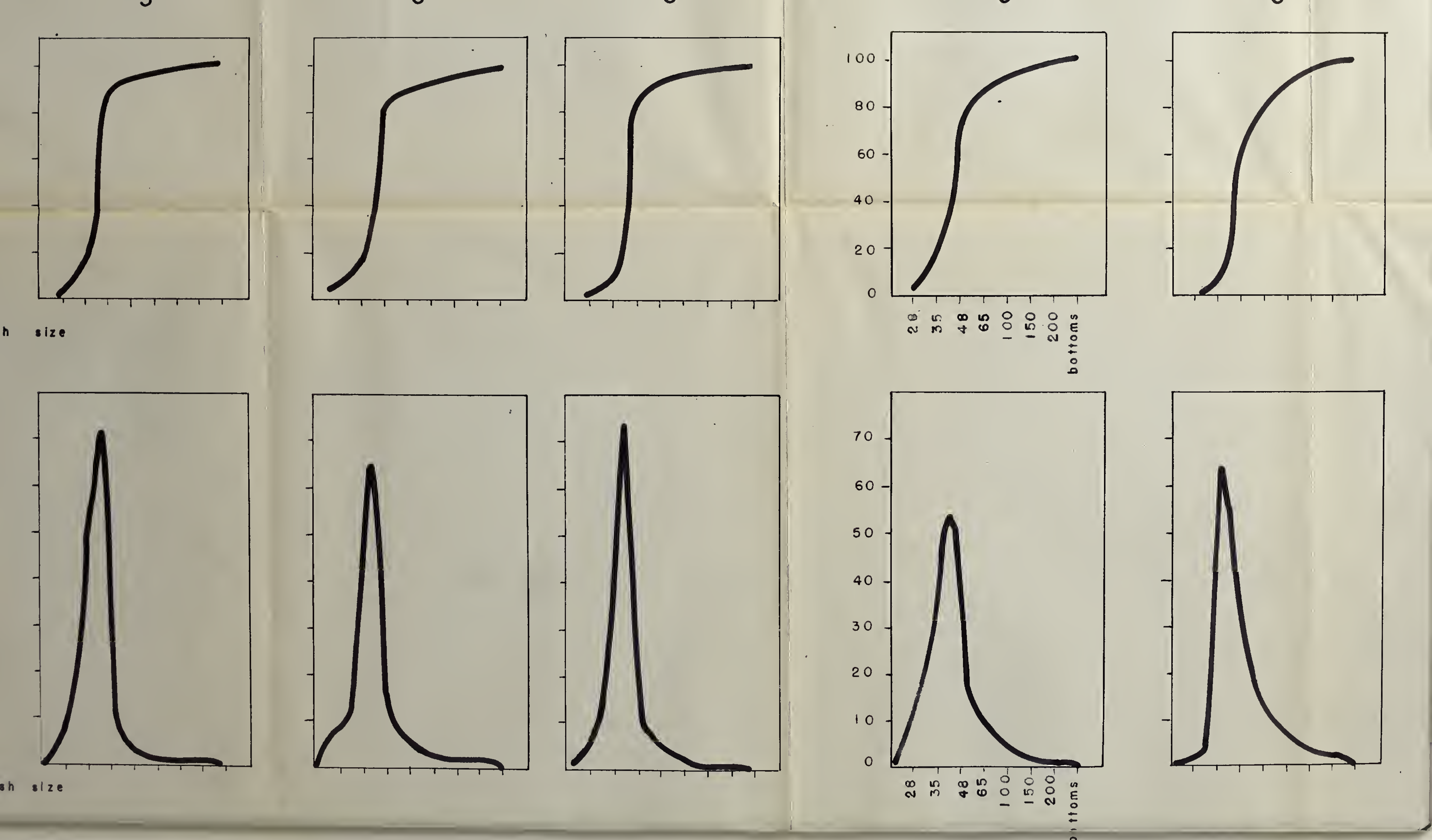
48
65
100
150
200
bottoms
mesh size



h size
sh size
100
80
60
40
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28
35
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65
100
150
200
bottoms
70
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40
30
20
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0
28
35
48
65
100
150
200
bottoms

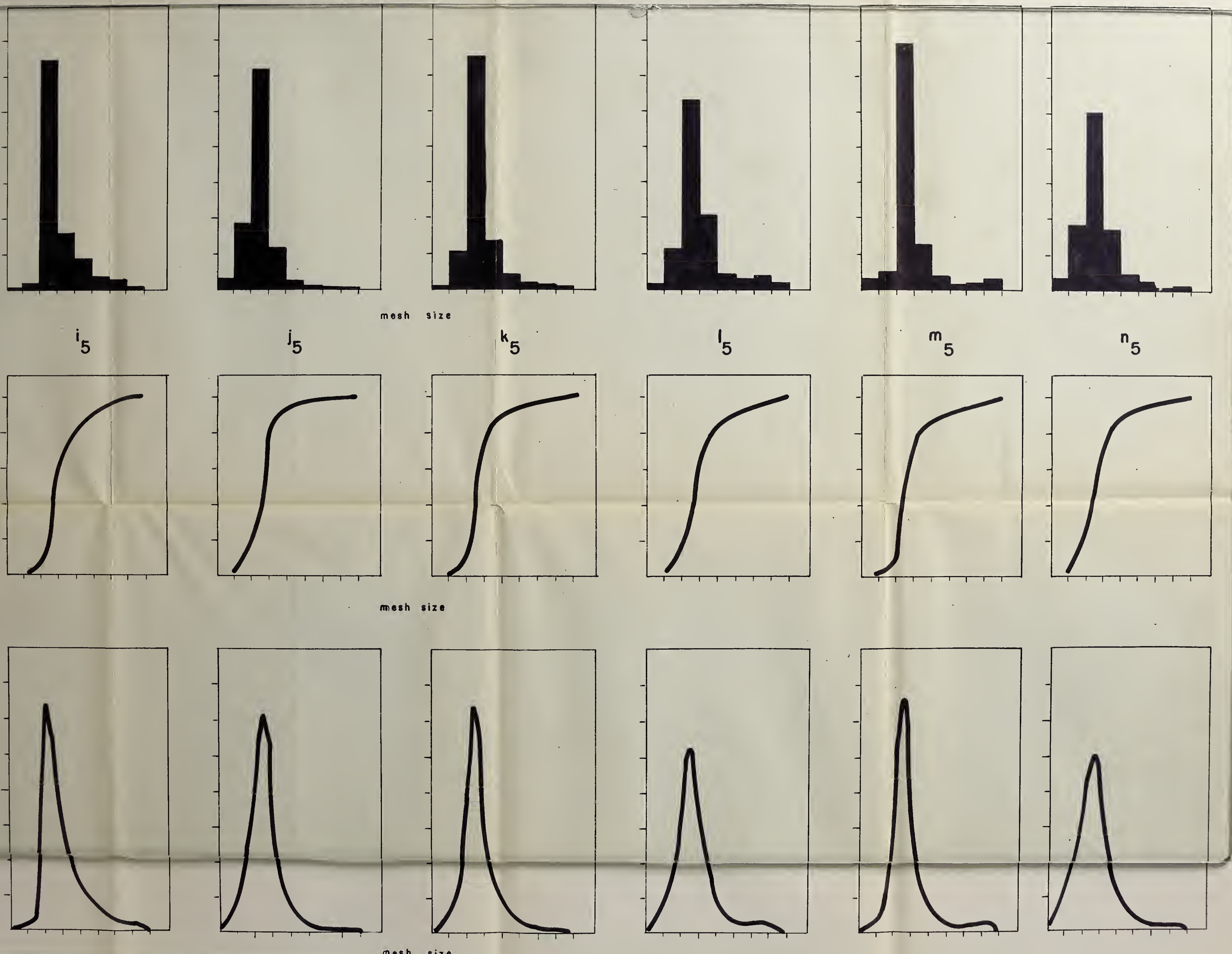
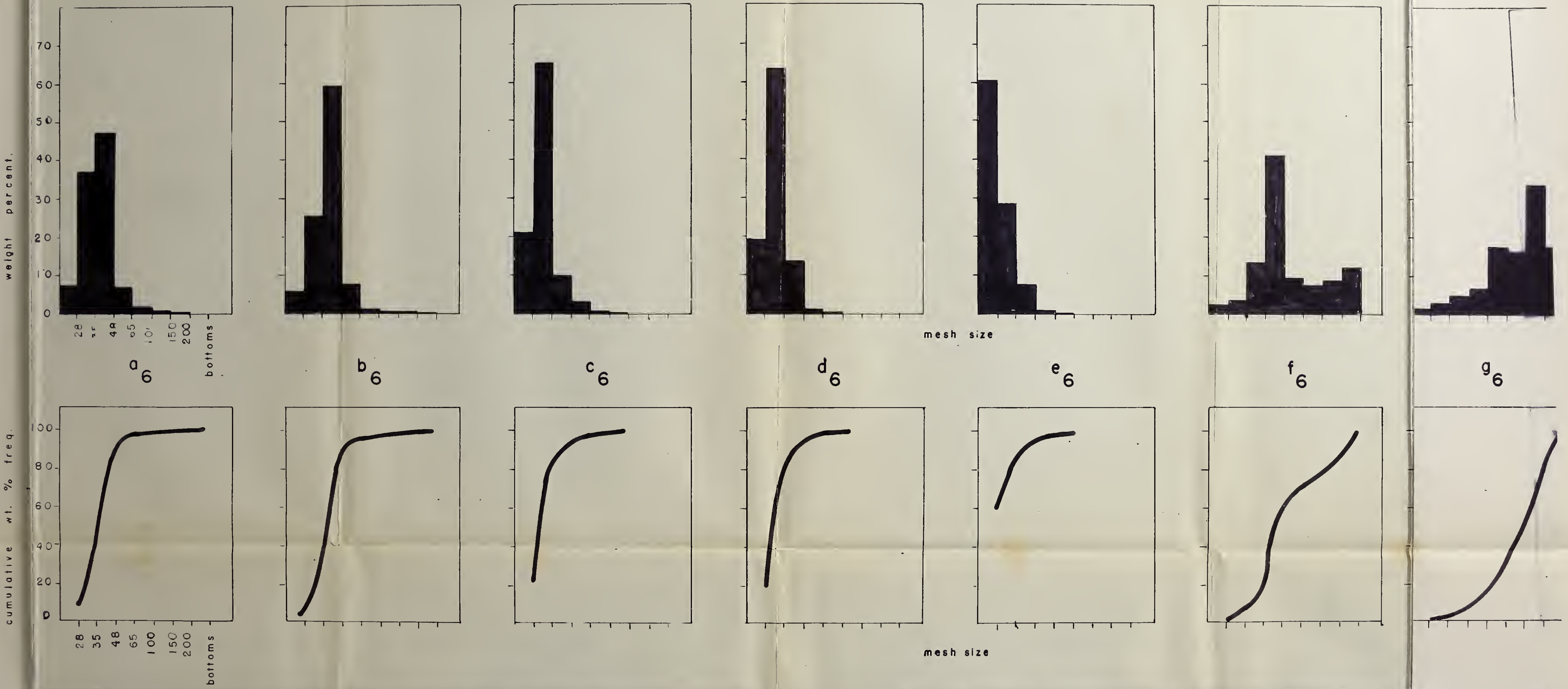

mesh size
i5
j5
k5
l5
m5
n5
mesh size
mesh size

Table 6.

Miscellaneous Sands.



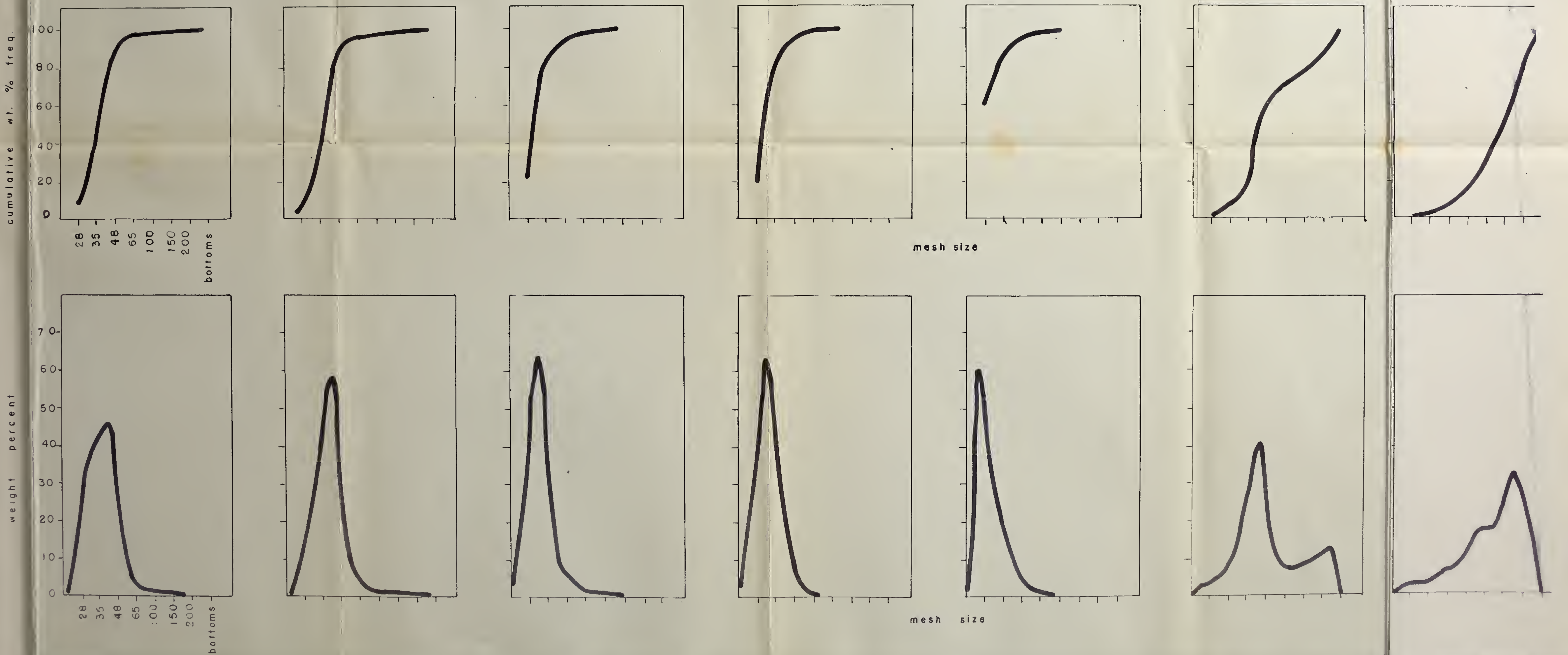

cumulative wt. % freq.
100
80
60
40
20
0
28
35
48
65
100
150
200
bottoms
mesh size
weight percent
70
60
50
40
30
20
10
0
28
35
48
65
100
150
200
bottoms
mesh size

Table 1.

SASKATCHEWAN SANDS

Heavy Mineral	Specimen No.							
	a_1	b_1	c_1	d_1	e_1	f_1	g_1	h_1
Amphibole group (tremolite, actinolite, hornblende)	c	c	C	C	C	C	C	C
Apatite	s	s	s	s	s	s	s	s
Biotite	r	r				R	R	
Chalcopyrite								
Chlorite	R	R	R	R			r	
Garnet	c	c	c	c	c	C	a	C
Haematite								
Ilmenite	R	r	S	S		r	r	S
Kyanite								
Leucoxene	r	r	r	r	r	r	r	r
Limonite	a	a	a	C	s	a	R	c
Magnetite	c	c	c	c	c	c	c	C
Muscovite								
Pyrite								
Pyroxene								
Rutile								
Staurolite	s	s	s	s	s	s	s	s
Tourmaline						R		
Zircon	R	r	S	R	R		R	R

Table 2.

BEDROCK, GRAY TILL, BROWN TILL, SILT TILL

Heavy Mineral	Specimen No.															
	a_2	c_2	d_2	e_2	f_2	g_2	h_2	i_2	j_2	k_2	l_2	m_2	n_2	o_2	p_2	q_2
Amphibole group (tremolite, actinolite, hornblende)		c	C	C	C	C	C	C	a	C	C	C	C	C	C	C
Apatite	r	c	r	r	R	r	c	c	C	c	s	s	s	s	S	
Biotite	s			r		R	R	r	R			R	r	r	r	R
Chalcopyrite																
Chlorite	S	s	S	r	s	S	R	r	R		R	r	r	S	s	s
Garnet	s	c	C	c	c	c	c	C	C	C	C	C	c	c	c	c
Haematite								R				R				
Ilmenite	r	s	S	c	s	c	r	S	S	S	S	s	c	s	c	c
Kyanite						R				R	R		R	r		R
Leucoxene		r	S	R		r	R		R		r	r	r	R	r	r
Limonite	c	r	s	c	c	C	C	C	C	c	c	c	C	a	a	a
Magnetite	c	c	s	c	c	c	s	s	s	s	s	c	c	c	c	c
Muscovite	S	R						R			R					
Pyrite						r										
Pyroxene																
Rutile	R	r					R	R	R	R				R		R
Staurolite		s	R	r	r	r	r	S	S	r	r	r	r		R	R
Tourmaline		s	R		R								R			R
Zircon	r	C	s	S	S	r	r	R	r		R	R		r	S	

Table 3.

INTERGLACIAL SANDS

Heavy Mineral	Specimen No.											
	a_3	b_3	c_3	d_3	e_3	f_3	g_3	i_3	j_3	k_3	l_3	m_3
Amphibole group (tremolite, actinolite, hornblende)	a	a	a	A	a	a	a	a	a	a	a	a
Apatite	c	c	C		S	S	S	r	S	r	r	S
Biotite	r			r	r				r		R	
Chalcopyrite					s							
Chlorite			R			R						r
Garnet	C	C	C	c	C	C	a	a	a	a	a	a
Haematite		R	R	R	R			R	R	R		
Ilmenite		r	r	r	r	r		r	r			
Kyanite	R											
Leucoxene	R	R	R	r	r	r	r	r	R	R	R	R
Limonite	a	c	c	a	c	c		s	c	S	s	s
Magnetite	r	r	r	S	s	s		s	s	r	r	r
Muscovite												
Pyrite					R							
Pyroxene								R	R			
Rutile										R		
Staurolite	s	s	s	s	s	s	s	s	s	s	s	s
Tourmaline												
Zircon	r				R		R					

Tooth observed in a_3.

Table 4.

SANDS UNDER SILT TILL

Heavy Mineral	Specimen No.										
	a_4	b_4	c_4	d_4	e_4	f_4	g_4	h_4	i_4	j_4	k_4
Amphibole group (tremolite, actinolite, hornblende)	a	a	a	a	a	a	a	a	A	A	a
Apatite	S	S	S		S	S	S		S	r	S
Biotite	R	R		R				R			
Chalcopyrite											
Chlorite		r		r		r	r	r			R
Garnet	C	C	C	C	C	C	C	c	c	S	c
Haematite	r			S		S	S	r	r		
Ilmenite		s		s	r		r	r	r	r	s
Kyanite	r	r			r		r		r		
Leucoxene	r	r	r	r	r	r	r	r	r	R	r
Limonite	a	a	a	a	a	a	a	a	A	s	
Magnetite	s	s	s	s	s	s	s	s	s	r	s
Muscovite											
Pyrite											
Pyroxene											
Rutile							R		R		
Staurolite	s	s	s	s	s	s	s	s	s	s	s
Tourmaline											
Zircon		S				r	r		S	r	r

Small tooth observed in d_4.

Table 5.

SANDS UNDER SILT TILL

Heavy Mineral	Specimen No.													
	a_5	b_5	c_5	d_5	e_5	f_5	g_5	h_5	i_5	j_5	k_5	l_5	m_5	n_5
Amphibole group (tremolite, actinolite, hornblende)	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Apatite		s	s	S		S	S		S		S	S	S	
Biotite	R	R		R	R	R		R	R	R				
Chalcopyrite														
Chlorite	r							r		r				
Garnet	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Haematite	R	R	R	R	R	R	R	R	R	R	R			
Ilmenite	r			r	r	r		r	r	r			r	
Kyanite			r				r				r			r
Leucoxene	r	r	r	r	r	r	r	r	r	r	r	r	r	r
Limonite	a	a	a	a	a	a	a	a	a	a	a	a	a	a
Magnetite	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Muscovite														
Pyrite														
Pyroxene	R	R												
Rutile														
Staurolite	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Tourmaline														
Zircon	S	S	S	S	S	S	S	S		S			S	

Table 6.

MISCELLANEOUS SANDS

Heavy Mineral	Specimen No.						
	a_6	b_6	c_6	d_6	e_6	f_6	g_6
Amphibole group (tremolite, actinolite, hornblende)	a	a	C	c	c	A	A
Apatite	r	S	r		r	c	r
Biotite						R	R
Chalcopyrite							
Chlorite	S	r				R	R
Garnet	C	C	c	r	c	c	c
Haematite	R						
Ilmenite	S	s	R		r	s	s
Kyanite						R	
Leucoxene	r	r	R	R	R	r	R
Limonite	A	a	S	a	c	c	c
Magnetite	s	s	S	a	c	s	s
Muscovite							
Pyrite	R						
Pyroxene							
Rutile						R	R
Staurolite	s	r	R			r	r
Tourmaline	r					R	r
Zircon	r					r	r

APPENDIX " E "

Tables 1 to 7

Table 1

EDMONTON SANDSTONE

Grain No.	Sphericity	Roundness
a	0.70	0.313
b	0.84	0.20
c	0.85	0.56
d	0.85	0.36
e	0.73	0.57
f	0.83	0.41
Average	0.80	0.41

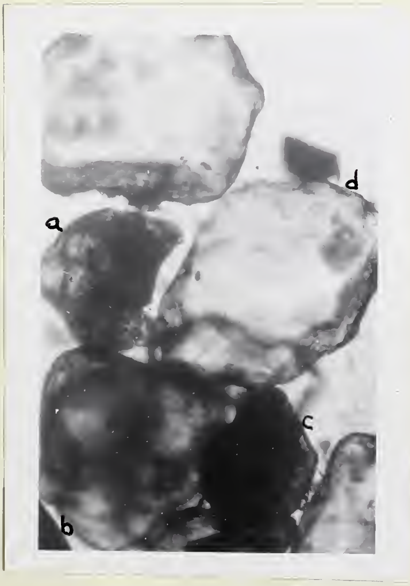
Sp. No. a_2 (x 125)

Sp. No. b_2 (x 125)

Table 2

SASKATCHEWAN SANDS

Grain No.	Sphericity	Roundness
a	0.71	0.354
b	0.81	0.327
c	0.71	0.590
d	0.77	0.452
e	0.67	0.470
f	0.73	0.712
g	0.87	0.550
Average	0.753	0.494



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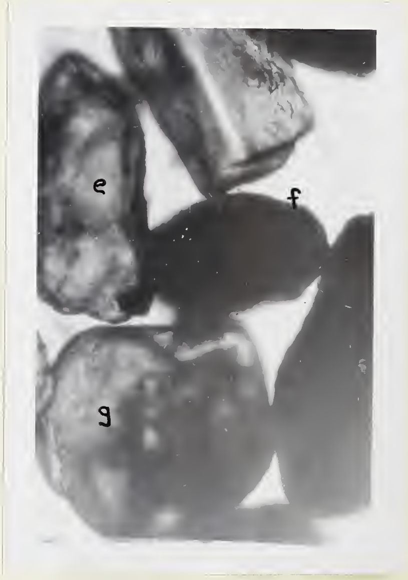
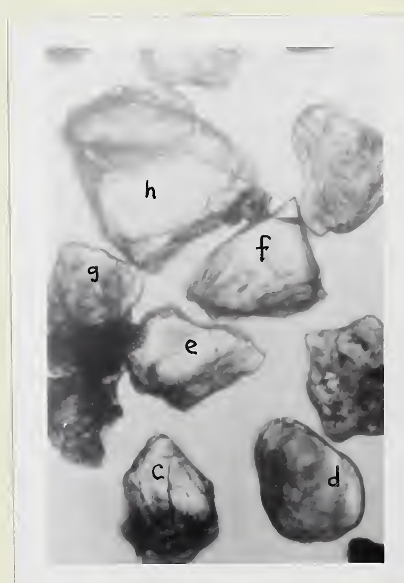


Sp. No. a_1 (x 125)

Table 3

GRAY TILL

Grain No.	Sphericity	Roundness
a	0.88	0.58
b	0.85	0.39
c	0.74	0.39
d	0.76	0.68
e	0.71	0.52
f	0.70	0.283
g	0.74	0.31
h	0.84	0.27
Average	0.779	0.427



Sp. No. d_2 (x 125)

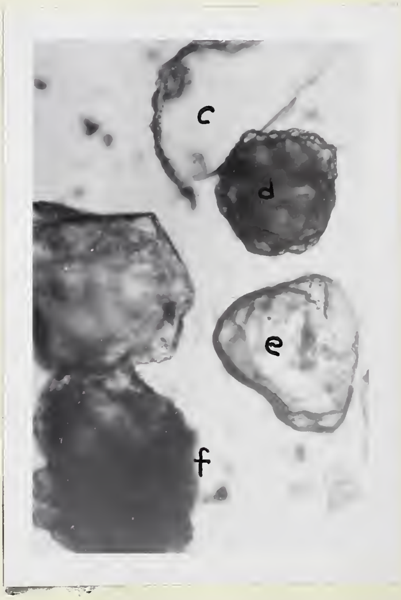
Sp. No. g_2 (x 125)

Table 4

INTERGLACIAL

Grain No.	Sphericity	Roundness
a	0.83	0.482
b	0.83	0.463
c	0.65	0.459
d	0.89	0.310
e	0.85	0.534
f	0.77	0.283
Average	0.803	0.422

Sp. No. b_3 (x 125)



Sp. No. d_3 (x 125)

Table 5

BROWN TILL

Grain No.	Sphericity	Roundness
a	0.83	0.35
b	0.83	0.43
c	0.83	0.26
d	0.85	0.49
e	0.83	0.40
Average	0.834	0.386

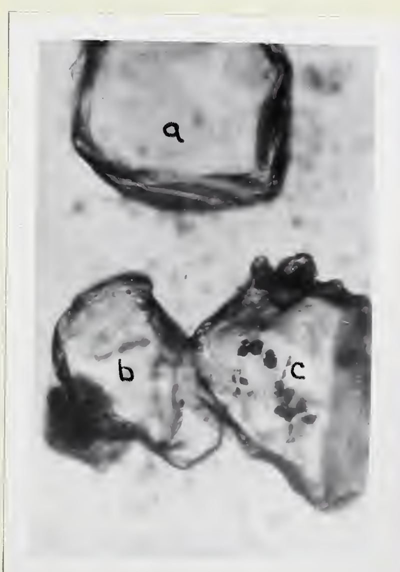
Sp. No. i_2 (x 125)

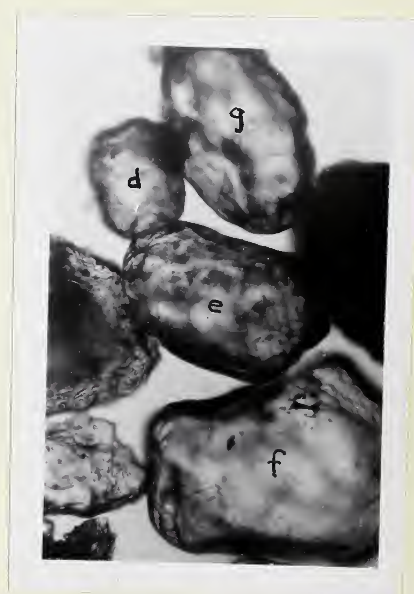
Sp. No. l_2 (x 125)

Table 6

UNDER SILT TILL

Grain No.	Sphericity	Roundness
a	0.87	0.214
b	0.75	0.555
c	0.85	0.447
d	0.85	0.715
e	0.77	0.520
f	0.77	0.428
g	0.73	0.520
Average	0.799	0.486





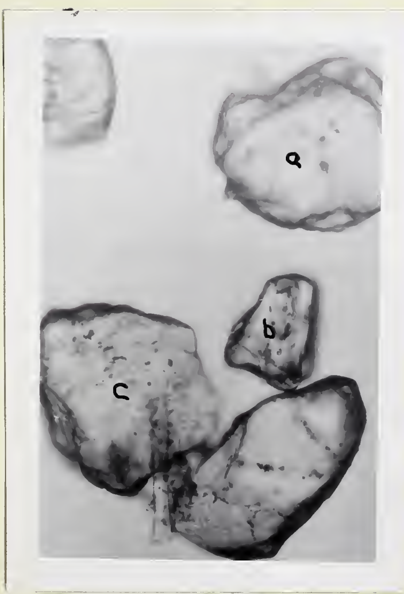
Sp. No. d_5 (x 125)

Sp. No. a_4 (x 125)

Table 7

SILT TILL

Grain No.	Sphericity	Roundness
a	0.91	0.57
b	0.87	0.53
c	0.90	0.36
d	0.93	0.65
e	0.94	0.45
f	0.73	0.31
g	0.85	0.54
Average	0.877	0.48



Sp. No. p_2 (x 125)

Sp. No. n_2 (x 125)

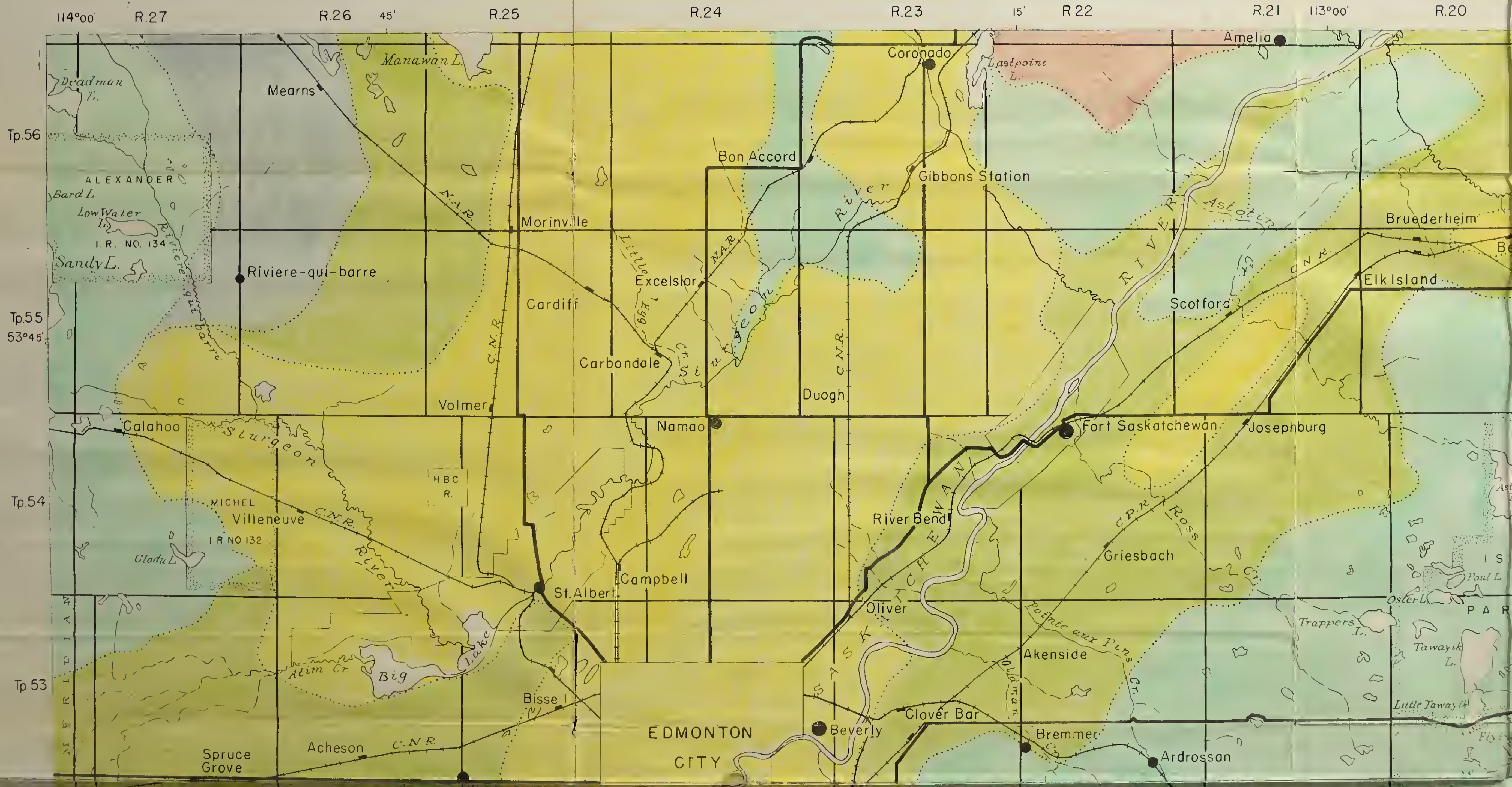
Glacial Map

GLACIAL MAP

OF

EDMONTON AREA.

SCALE 1 INCH TO 3 MILES.

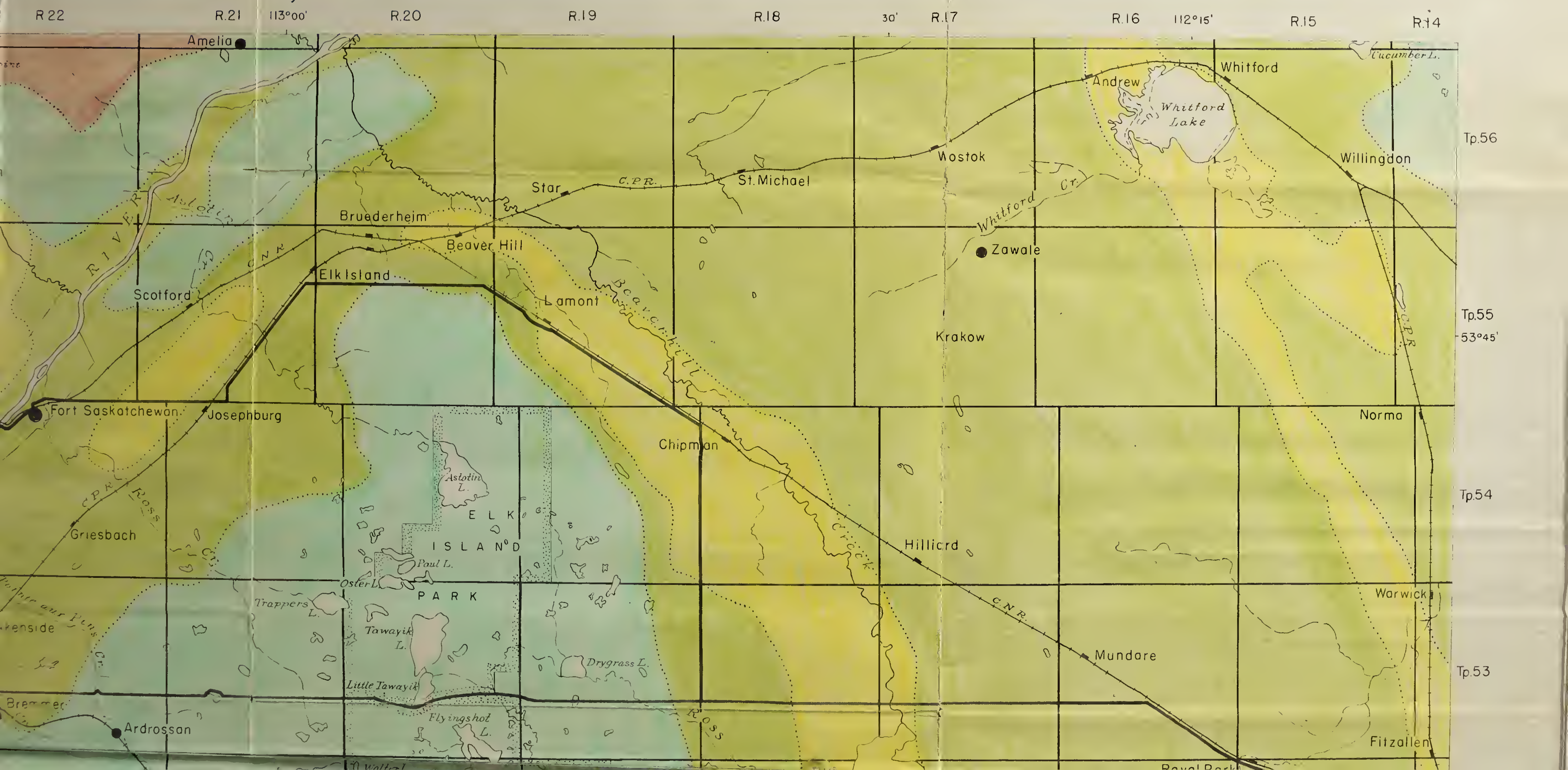


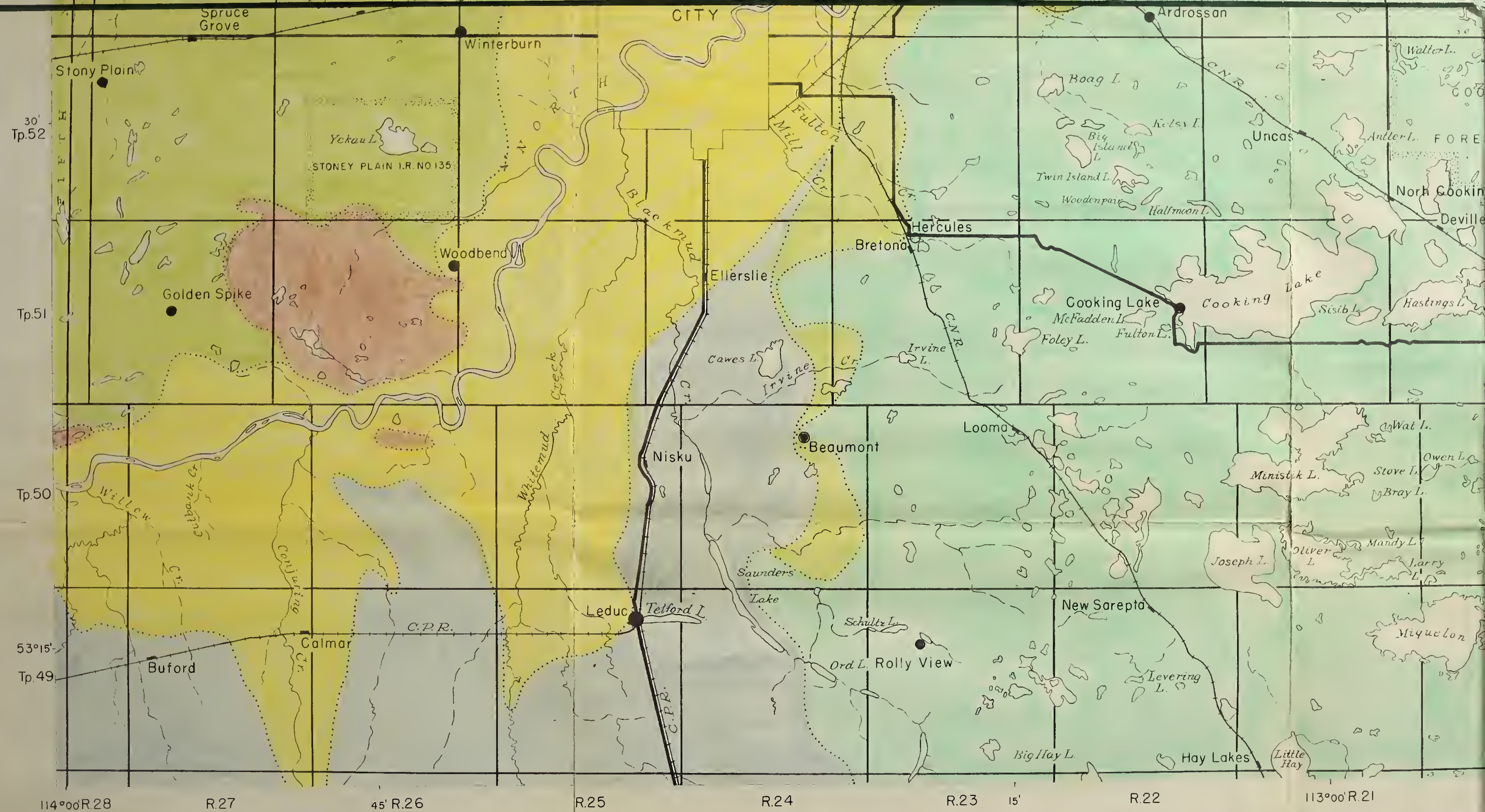
GLACIAL MAP

OF

EDMONTON AREA.

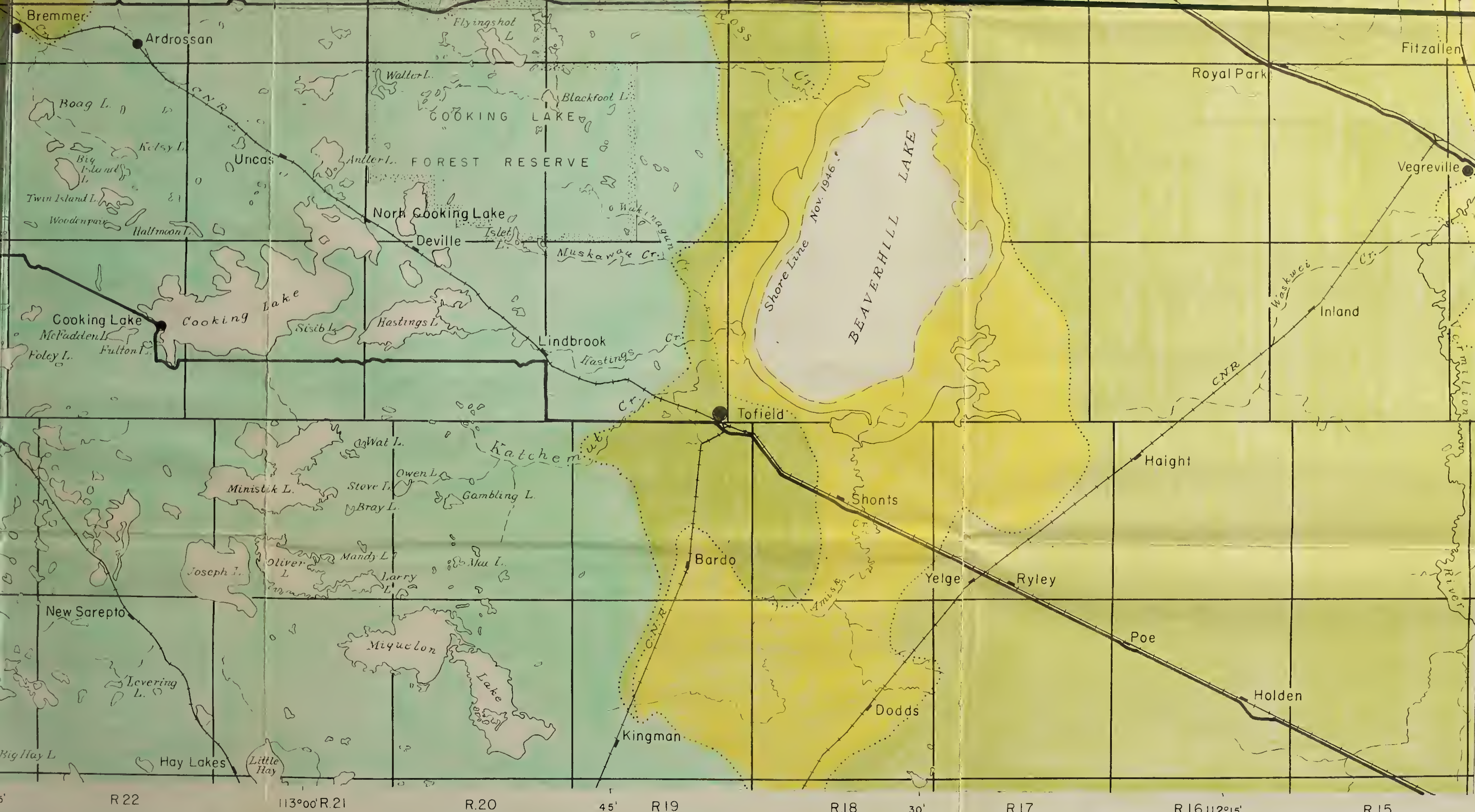
SCALE 1 INCH TO 3 MILES.





— LEGEND —

Morainal topography.	Swell and Swale and Gently Undulating topography.	Gently Undulating topography - influenced by underlying bedrock.



— LEGEND —

Gently Undulating topography- influenced by underlying bedrock.

Flat topography- area of old laking.

Sand areas- dunes present, no observable till.